Journal
of
The Franklin Institute
Devoted to Science and the Mechanic Arts

Vol. 187 JUNE, 1919 No. 6

TREE TELEPHONY AND TELEGRAPHY.*

BY
MAJOR GENERAL GEORGE O. SQUIER,
Chief Signal Officer, United States Army.
Member of the Institute.

I. FOREWORD.

In 1904 the author conducted some experiments with a view to utilizing growing trees as antennæ for radio telegraphy and discovered the efficacy, in a general way, of using a direct metallic contact to certain trees (principally eucalyptus) to increase the audibility of radio signals.

My attention was first called to this phenomenon during the course of summer manœuvres of the Army at Camp Atascadero, California, where, due to the prevalence of the dry season and the unusual character of the soil, it was found that the regular Army buzzer telephone and telegraph sets were inoperative with any ordinary ground or earth but became operative when connected to a metallic nail driven in the trunk or roots of a tree. This incident led the author to pursue the subject experimentally in the autumn of 1904, continuing the experiments to the range of frequencies then employed in radio telegraphy.

From the account of these experiments I quote the following selected paragraphs: [1]

* Communicated by the author.

[1] Reference. "On the Absorption of Electromagnetic Waves by Living Vegetable Organisms." By George O. Squier, Ph.D., Major, Signal Corps, U. S. A. Official Report to the War Department on the Military Manœuvres in the Pacific Division, 1904.

[Note.—The Franklin Institute is not responsible for the statements and opinions advanced by contributors to the JOURNAL.]

COPYRIGHT, 1919, by THE FRANKLIN INSTITUTE.

"It would seem that living vegetation may play a more important part in electrical phenomena than has been generally supposed. We have seen that living vegetable organisms absorb and conduct electromagnetic oscillations over a wide range of the electromagnetic spectrum, beginning with sunlight, whose electrical action in the plant cell is at present little understood, and extending to waves of identical character, but of immensely greater lengths, such as Hertzian radiation, telephonic waves, and oscillations of the ordinary low frequencies used in commercial electric transmission lines. Disruptive discharges between vegetable electrodes, and electrostatic effects between vegetable surfaces are easily produced.

Floraphone short-wave receiving apparatus.

"In view of what has been accomplished in space telegraphy within the last seven or eight years, it is difficult to predict to what extent this means of communication may be ultimately developed. If, as indicated above in these experiments, the earth's surface is already generously provided with efficient antennæ, which we have but to utilize for such communication, even over short distances, it is a fascinating thought to dwell upon in connection with the future development of the transmission of intelligence.

"Since a transmitting station is a central point for electromagnetic waves sent out in all directions over the surface of the earth, a large class of information, such as meteorological reports, crop reports, and general news items of interest to all, may in time be sent from central points, to be received at many places within the radius of influence of the signal station, and this, too, by the simplest forms of apparatus.

"It is seen that a growing tree, covered with foliage, is influenced inductively by electrical disturbances outside of itself, and in fact becomes generally responsive to induced electrical oscillations. It should offer, therefore, a promising means of studying meteorological effects of an electrical character, particularly those of lightning discharges, and electricity of the air. One of the first practical rules for the preservation of life against lightning is to avoid the vicinity of a tree.

"Our great forest areas may exercise an influence in maintaining a general equilibrium between the electrical charges of the upper atmosphere and the earth, which has not been fully realized. On this point, comparisons

Floraphone long-wave receiving apparatus, with direction finder and "barrage" receiver.

between observatories from the interior of great desert areas devoid of any vegetation, with those from other portions of the earth's surface well covered with forests, would be instructive.

"From this viewpoint, the general surface of the earth may be considered as supplied by nature with innumerable meteorological observation towers, which may be employed by means of apparatus involving principles already well known to science.

"In conclusion, it is believed that vegetation should be studied more systematically, from a distinctly physical standpoint than has been done in the past. Physics has been said to be the mother of all sciences, and more the physical method of studying all science is proving to be the true one, as is

evidenced by the great advance in recent years, in comparatively new branches of scientific work, such as Astrophysics and Physical Chemistry. Has not the time arrived for a more systematic study of Physical Botany, in the light of the new electrical theory of matter?"

II. TREE ANTENNÆ.

In connection with the organization and development of Transatlantic radio reception which was carried out during the period of the war to provide against the possibility of the interruption of the submarine cable system, the Signal Corps established a

Floraphone radio telephone apparatus arranged for transmitting and receiving with tree antenna.

chain of special receiving stations in different parts of the United States to copy and record enemy and allied radio messages from European stations for the information of our Army General Staff.

In the prosecution of this work, directions were given to the Signal Corps Laboratory at Camp Alfred Vail, Little Silver, New Jersey, and also to the experimental staff in Washington to test the efficiency of growing trees as receiving antennæ in connection with this service, using the vastly superior technic and facilities now represented in the radio art as compared with the crude

apparatus with which the discovery was made in 1904. With a collection of apparatus representing the most advanced state of the radio art, the problem, as a war measure, was attacked anew and has now reached a point when a very brief outline of some of the physical results obtained should be presented in the interests of the development of the art in general. Since the phenomena involved embrace a variety of physical problems rather than strictly engineering ones, these data are presented to the Physical Society in the hope that some of its members may see in the experiments some points of departure for further research.

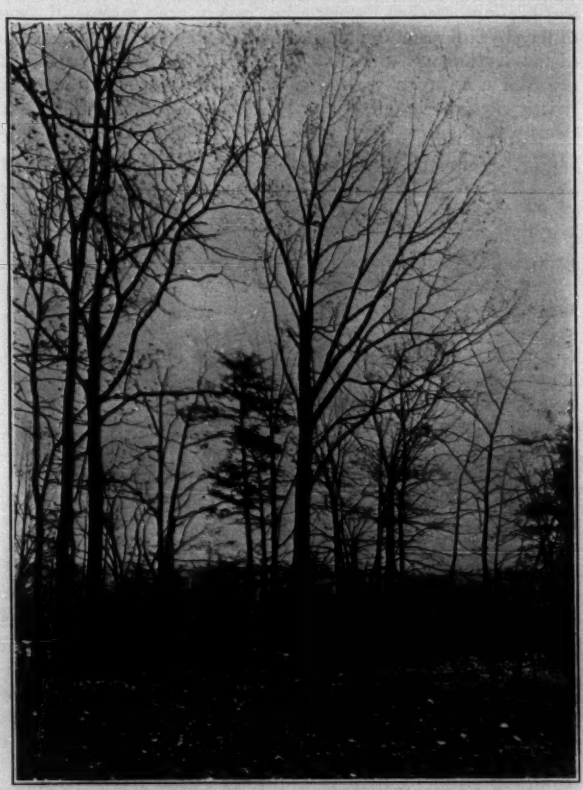
U. S. Signal Corps floraphone and floragraph laboratory and station, Grant Road, District of Columbia, April 18, 1919.

It was immediately discovered that with the sensitive amplifiers now in use it was possible to receive signals from the principal European stations by simply laying a small wire netting on the ground beneath the tree and connecting an insulated wire to a nail driven in the tree well within the outline of the tree top.

This encouraging first result justified a more careful examination of the phenomena and the most suitable arrangement of circuits for the purpose.

Without entering into the details of these preliminary experiments it may be said that one of the best receiving arrangements

is found to be an elevated tree earth-terminal in the upper part of the tree top as described later, and an earth consisting practically of several short pieces of insulated wire sealed at the outer



"Floraphone," oak tree used as antenna.

ends radiating out from a common centre, and buried a few inches beneath the surface of the ground in the neighborhood of the tree.

It was soon found that a tree-antenna could be used efficiently as a multiple receiving set over widely different wave lengths, receiving either from separate terminals at the same or different heights of the tree or in series from the same terminal.

This same type of circuit was employed in an inverse manner for telephonic transmitting purposes, and although the experiments thus far have been limited to short distances, it was found that 2-way telephonic communication was easily established with remarkably low values of transmitting antenna current.

The flexibility of this arrangement is very striking. The linking up of wire and wireless methods was found to be convenient and efficient. Radio telephonic messages from airplanes were readily received by the tree-antenna arrangement and transferred thence to the wire system of the City of Washington and finally received at any point desired.

Furthermore, telephonic transmission through the tree-antenna was received by another tree-antenna, and automatically returned to the sender on a wire system, thus making the complete circuit. Long distance reception on any wave length from all the larger European stations and from our ships at sea was easily accomplished and traffic copied on a twenty-four-hour schedule by the regular enlisted operators of the Signal Corps. A small portable house serving as a field laboratory was erected in the midst of the forest area on Grant road, Washington, D. C., between the Bureau of Standards and Chevy Chase, Maryland, and here was assembled a collection of the most efficient vacuum tube amplifiers developed to date by the Signal Corps of the Army, the Navy, the British and the French, and of commercial firms in the United States. With these unusual facilities it was a matter of a few days to test out, at least in a superficial manner, a large number of proposed arrangements using trees as antennæ. Second Lieutenants H. A. Browning and M. C. Batsel, Signal Corps, have been in charge of this field laboratory.

The following data on the electrical constants of tree-antennæ have been obtained by Captain F. E. Pernot, Signal Corps, in charge of the Signal Corps radio research laboratory at the Bureau of Standards.

Physical Properties.

Early experiments performed by Lieutenant J. A. Riner and Lieutenant H. A. Browning, Signal Corps, served to ascer-

tain the relation between the audibility of received signals and the height of the tree contact above the ground, but gave no data concerning the magnitudes of the electrical properties which characterized such an antenna system. It is the intention here to examine more closely into such properties.

The two quantities which serve to characterize an antenna system are (1) the apparent impedance of the antenna as measured at the particular frequency in question from the two terminals which lead to the receiving set, and (2) the electromotive force at these terminals when they are open-circuited and the intensity of the electromagnetic radiation impinging upon the antenna system is unity.

Antenna Impedance.

The antenna impedance Z depends upon the frequency for any given system, and consists of the two components, resistance and reactance, the latter usually being condensive. It is expressed in complex quantities as:

$$z = r - j\,x$$

r = resistance in ohms

$$x = \frac{1}{2\pi f C}$$ reactance in ohms

r and x are to be taken as the equivalent series constants at frequency f. To distinguish these series constants from the constants of a parallel-connected system, having the same impedance, the following notation may be used:

r_s = series resistance
C_s = series capacity
C_p = parallel capacity
r_p = parallel resistance

These quantities are related by

$$r_s = \frac{1}{1+(r_p\omega C_p)^2}\, r_p \quad \text{and} \quad C_s = \frac{1+(r_p\omega C_p)^2}{(r_p\omega C_p)^2}\, C_p$$

where $\omega = 2\pi f$

In some cases it is more convenient to determine the series capacity and resistance than the similar parallel quantities and *vice versa*. The above equations permit of ready conversion from one form to the other.

The following experiments were made on a pine tree shown in Plate I. The general location of the tree and its surroundings are shown in Plate II.

PLATE I.

Pine tree used in experiments. Average diameter about 25 cm. Signal Corps floraphone laboratory at the right.

Tree contact was made through copper nails driven three inches into the tree. Ground contact was made through a bundle of copper wire buried three feet deep in moist soil. Three grounds were installed so that the individual resistances could be deter-

mined. An average value for this resistance with direct current was 150 ohms. At radio frequencies, on account of capacity effects, this resistance was much smaller.

Using the substitution method, measurements of the apparent series capacity and resistance of the lead alone and of the lead attached to nails driven into the tree at various heights were made at different frequencies. In all cases the lead was of just sufficient length to reach to the point of contact, whether connected electrically to the nail or free.

PLATE II.

Portion of surroundings of pine tree. Tree used indicated by arrow.

The original data are given in Tables I and II. From these data after cross-plotting to eliminate irregularities, consistent and regular families of curves, as shown in Figs. 1, 2, 3 and 4, were obtained. Wave lengths from 150 to 700 metres are covered.

The small change in the electrostatic capacity occasioned by making electrical contact with the tree, while all other conditions remain unaltered, is to be remarked and also the large increase in resistance under the same conditions. The increase in resistance is particularly pronounced for small heights and long wave lengths.

TABLE I.

Apparent Series Capacity and Resistance of Antenna Lead.

(Measured between ground and lower end of conductor, upper end of which reached to but was not connected with, a nail in the tree at height indicated. Substitution method of measurement.)

Height h metres.	Wave length λ metres.	Frequency f Cyc./sec.	Resistance r_1 ohms.	Capacity C_1 micro-micro-farads.
4.6	152	1,975,000	118	70
4.6	300	1,000,000	133	65
4.6	500	600,000	228	65
4.6	700	429,000	310	65
4.6	980	306,000	400	65
6.1	109	2,750,000	61	100
6.1	161	1,863,000	120	90
6.1	300	1,000,000	179	85
6.1	500	600,000	326	80
6.1	750	400,000	500	85
8.5	111	2,700,000	80	100
8.5	160	1,875,000	94	80
8.5	275	1,092,000	136	80
8.5	386	777,000	196	80
8.5	700	429,000	420	90
8.5	1,000	300,000	490	90
10.7	102	2,942,000	92	340
10.7	126	2,380,000	108	150
10.7	183	1,640,000	128	120
10.7	280	1,074,000	206	110
10.7	380	789,000	290	110
10.7	480	625,000	390	100
10.7	805	373,000	710	110
10.7	905	331,000	820	110
12.2	100	3,000,000	290	210
12.2	130	2,308,000	109	150
12.2	186	1,615,000	160	120
12.2	288	1,042,000	270	110
12.2	435	690,000	386	110
12.2	635	472,000	680	110
12.2	810	370,000	600?	100
12.2	810	370,000	860	100
14.0	110	2,727,000	65	440
14.0	147	2,041,000	100	190
14.0	198	1,516,000	140	152
14.0	304	987,000	209	148
14.0	445	674,000	330	145
14.0	880	341,000	710	148
17.4	127	2,360,000	67	570
17.4	164	1,829,000	92	240
17.4	220	1,364,000	121	200
17.4	340	883,000	182	180
17.4	485	618,000	276	174
17.4	787	382,000	450	190
17.4	870	345,000	517	185

TABLE II.

Apparent Series Capacity and Resistance of Antenna Lead Connected to the Tree.

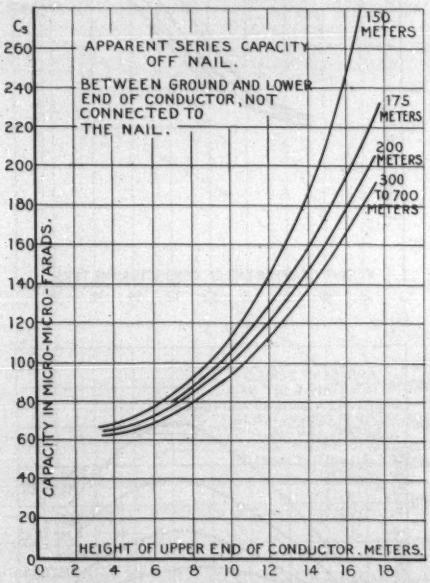
(Measured between ground and lower end of conductor connected to a nail in the tree at the height indicated. Substitution method of measurement.)

Height h metres.	Wave length λ metres.	Frequency f cyc./sec.	Resistance r_x ohms.	Capacity C_x micro-micro-farads.
4.6	103	2,910,000	248	90
4.6	107	2,800,000	122	90
4.6	153	1,962,000	211	85
4.6	235	1,276,000	300	85
4.6	354	847,000	440	85
4.6	595	504,000	1,110	85
4.6	650	462,000	1,290	85
4.6	885	339,000	2,050	70
6.1	117	2,563,000	123	115
6.1	165	1,820,000	202	95
6.1	260	1,154,000	317	90
6.1	382	786,000	660	90
6.1	440	682,000	625	95
6.1	500	600,000	85?	105
6.1	525	572,000	820	105
6.1	550	546,000	910	135
6.1	745	403,000	1,260	130
6.1	800	375,000	1,590	100
8.5	103	2,910,000	230	205
8.5	113	2,653,000	192	110
8.5	156	1,923,000	245	85
8.5	280	1,072,000	418	90
8.5	395	760,000	665	95
8.5	700	428,000	1,500	110
10.7	102	2,940,000	220	110
10.7	137	2,190,000	118	160
10.7	190	1,579,000	165	130
10.7	290	1,034,000	286	120
10.7	346	868,000	384	120
10.7	500	600,000	630	130
10.7	800	375,000	1,160	140
12.2	102	2,940,000	210	670
12.2	133	2,250,000	127	150
12.2	185	1,622,000	196	130
12.2	288	1,042,000	325	110
12.2	415	722,500	553	120
12.2	690	434,000	1,060	130
12.2	740	405,500	1,150	130
14.0	108	2,780,000	144	780
14.0	144	2,083,000	130	203
14.0	200	1,500,000	170	163
14.0	312	961,000	280	148
14.0	445	675,000	476	145
14.0	805	372,000	980	150
14.0	835	359,000	980	166

TABLE II.—*Continued.*

Height h metres.	Wave length λ metres.	Frequency f cyc./sec.	Resistance r_s ohms.	Capacity C_s micro-micro-farads.
17.4	130	2,309,000	66	640
17.4	165	1,820,000	109	260
17.4	220	1,360,000	134	200
17.4	343	873,000	200	185
17.4	490	612,500	325	180
17.4	870	344,000	596	181
17.4	875	343,000	606	185
17.4	925	323,700	670	180

FIG. 1.



It is interesting to note that no correspondence is to be observed between the resistance curves, as determined by these measurements, and the curves representing the radiation resistance of

FIG. 2.

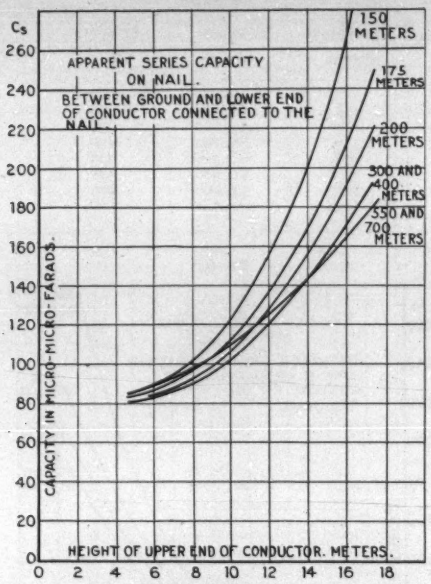
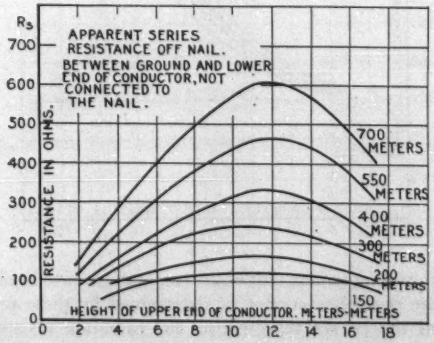

Cs
APPARENT SERIES CAPACITY ON NAIL.
BETWEEN GROUND AND LOWER END OF CONDUCTOR CONNECTED TO THE NAIL.
150 METERS
175 METERS
200 METERS
300 AND 400 METERS
550 AND 700 METERS
CAPACITY IN MICRO-MICRO-FARADS.
HEIGHT OF UPPER END OF CONDUCTOR. METERS.
0 20 40 60 80 100 120 140 160 180 200 220 240 260
0 2 4 6 8 10 12 14 16 18

FIG. 3.


Rs
APPARENT SERIES RESISTANCE OFF NAIL.
BETWEEN GROUND AND LOWER END OF CONDUCTOR, NOT CONNECTED TO THE NAIL.
700 METERS
550 METERS
400 METERS
300 METERS
200 METERS
150 METERS
RESISTANCE IN OHMS.
HEIGHT OF UPPER END OF CONDUCTOR. METERS.
0 100 200 300 400 500 600 700
0 2 4 6 8 10 12 14 16 18

a simple vertical wire. The latter curves are parabolas (as functions of the height) given by the equation:

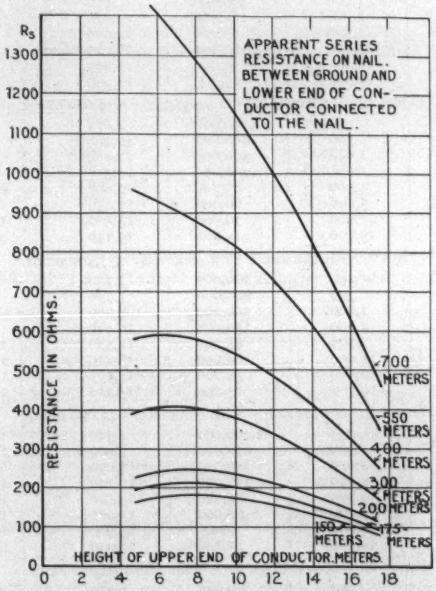
$$\text{Radiation resistance} = 400\left(\frac{h}{\lambda}\right)^2$$

where h = height of vertical wire

λ = wave length.

The coefficient in this equation is based upon a form factor of approximately ½ corresponding to values of λ large in comparison with $4h$. (See Zenneck, "Wireless Telegraphy," page 170.)

FIG. 4.



The explanation of such large resistance values in case of tree antennæ is probably to be found in the effect of the immediate proximity of partially conducting media to the conducting lead.

For long waves (low frequencies) the substitution method was not found satisfactory, so another method, in which the

TABLE III.

Apparent Resistance and Capacity Considered as Elements in Parallel.

(Measured between ground and lower end of conductor attached to a nail in the tree at the height indicated. Measured by shunting the antenna system around a known condenser and noting the change in resistance and capacity of the circuit caused thereby.)

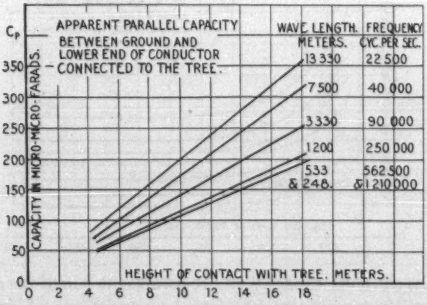
Height of contact h metres.	Wave length λ metres.	Frequency f cyc./sec.	Resistance shunt r_p ohms.	Capacity shunt C_p micro-micro-farads.
Direct current resistance with ohmmeter = 38,000 ohms.				
4.6	250	1,200,000	7,910	45.5
4.6	500	600,000	15,780	61.8
4.6	1,000	300,000	16,900	71.5
4.6	2,000	150,000	21,220	71.5
4.6	3,500	85,700	24,900	87.8
4.6	5,000	60,000	26,220	87.8
4.6	10,000	30,000	26,800	87.8
4.6	19,700	15,200	27,900	81.3
Direct current resistance with ohmmeter = 39,000 ohms.				
6.1	250	1,200,000	4,675	74.8
6.1	500	600,000	10,900	71.5
6.1	1,000	300,000	11,080	84.5
6.1	2,000	150,000	11,510	81.3
6.1	3,500	85,700	16,650	133.3
6.1	5,000	60,000	17,850	104.0
6.1	10,000	30,000	18,500	120,5
6.1	19,700	15,200	19,230	325.0
Direct current resistance with ohmmeter = 37,500 ohms.				
8.5	250	1,200,000	3,350	84.5
8.5	500	600,000	7,730	94.2
8.5	1,000	300,000	8,080	58.5
8.5	2,000	150,000	10,400	87.8
8.5	3,500	85,700	12,520	123.5
8.5	5,000	60,000	13,220	136.5
8.5	10,000	30,000	14,191	188.5
8.5	19,700	15,200	15,420	162.5
Direct current resistance with ohmmeter = 44,000 ohms.				
10.7	250	1,200,000	2,540	110.5
10.7	500	600,000	7,090	110.5
10.7	1,000	300,000	8,090	113.7
10.7	2,000	150,000	10,720	113.7
10.7	3,500	85,700	13,140	130.0
10.7	5,000	60,000	14,090	162.5
10.7	10,000	30,000	15,500	191.7
10.7	19,700	15,200	17,050	195.0
Direct current resistance with ohmmeter = 50,000 ohms.				
12.2	250	1,200,000	1,980	156.0
12.2	500	600,000	6,250	133.3
12.2	1,000	300,000	7,180	139.7
12.2	2,000	150,000	12,780	149.5
12.2	3,500	85,700	12,080	191.8
12.2	5,000	60,000	13,320	211.2
12.2	10,000	30,000	15,180	273.0
12.2	19,700	15,200	17,670	325.0

TABLE III.—*Continued.*

Height of contact h metres.	Wave length λ metres.	Frequency f cyc./sec.	Resistance shunt r_p ohms.	Capacity shunt C_p micro-micro-farads.
Direct current resistance with ohmmeter = 60,000 ohms.				
14.0	250	1,200,000	1,920	159.2
14.0	500	600,000	4,600	159.2
14.0	1,000	300,000	7,530	175.5
14.0	2,000	150,000	10,490	172.2
14.0	3,500	85,700	13,480	188.5
14.0	5,000	60,000	15,180	227.5
14.0	10,000	30,000	17,720	270.0
14.0	19,700	15,200	20,900	390.0
Direct current resistance with ohmmeter = 105,000 ohms.				
17.4	250	1,200,000	2,180	172.2
17.4	500	600,000	6,780	172.2
17.4	1,000	300,000	16,330	195.0
17.4	2,000	150,000	16,420	214.5
17.4	3,500	85,700	23,190	234.0
17.4	5,000	60,000	27,900	247.0
17.4	5,000	60,000	29,500	247.0
17.4	10,000	30,000	38,200	302.2
17.4	19,700	15,200	47,400	325.0

antenna of unknown properties was shunted around a condenser which constituted a portion of a resonant circuit, was used. This

FIG. 5.



method of measurement yields the apparent values of the antenna constants when they are considered as elements in parallel.

Original data so obtained are shown in Table III. For these

data the antenna lead was connected to the tree, and from it, after cross-plotting to eliminate accidental errors, the curves shown in Figs. 5 and 6 were obtained. The apparent capacity curves in Fig. 5 are instructive, indicating, as they do, a capacity proportional to the height of contact.

FIG. 6.

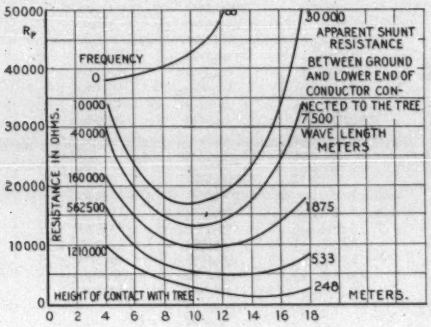
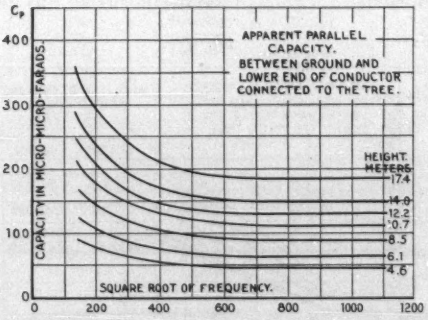


FIG. 7.



Besides showing capacity and resistance as functions of height of contact, they may also be plotted as functions of frequency, or, as happens to be more convenient in this case, the square root of frequency. Such curves are shown in Figs. 7 and 8. Taking a number of representative points from these curves of apparent

shunt characteristics, the values of the equivalent series characteristics were calculated by the aid of the equations previously given. The data given in Table IV and shown plotted in Figs. 9 and 10 were thus obtained.

FIG. 8.

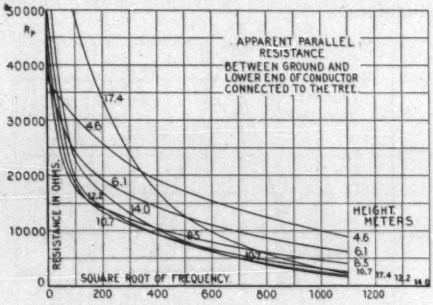


TABLE IV.

Apparent Resistance and Capacity Considered as Elements in Series.

(Calculated from data taken from the curves in Figs. 7 and 8.)

C_s = Capacity in micro-micro-farads.

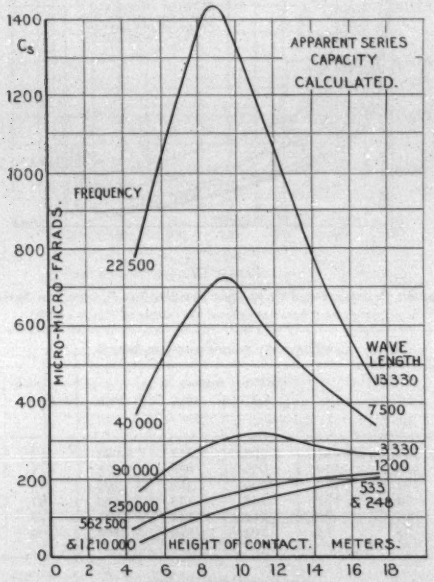
Frequency f.	Height in metres, h. 4.6	6.1	8.5	10.7	12.2	14.0	17.4
22,500	794	1,031	1,465	1,212	1,044	763	432
40,000	380	510	699	658	575	471	346
90,000	162	220	299	320	309	285	264
250,000	78	107	148	173	189	197	210
562,500	59	80	112	142	161	177	197
1,210,000	54	73	103	139	168	195	206

r_s = Resistance in ohms.

Frequency f.	Height in metres, h. 4.6	6.1	8.5	10.7	12.2	14.0	17.4
22,500	24,900	18,900	13,500	12,700	12,400	12,300	8,300
40,000	20,400	15,300	11,100	9,700	9,200	8,300	4,500
90,000	13,500	10,100	7,320	5,960	5,210	4,250	2,060
250,000	5,780	4,330	3,170	2,410	2,040	1,580	770
562,500	2,130	1,640	1,220	960	840	680	330
1,210,000	750	590	460	430	420	370	200

Certain portions of the curves in Figs. 7 and 8 and of those in Figs. 2 and 4, overlap and therefore the results may be compared. Such a comparison indicates some discrepancies, but these may be explained by the fact that the measurements were made at different dates and after the tree had undergone widely different weather conditions.

FIG. 9.

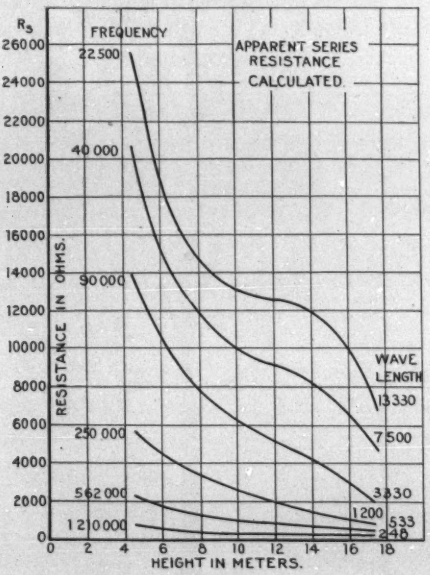


Referring to the general theory of alternating current systems it can be shown that the receiver constants for which a maximum energy extraction from the antenna is obtained are: (1) The receiver inductance should be such as to resonate with the apparent antenna capacity at the frequency in question. (2) An effective receiver resistance equal to the apparent resistance of the antenna at the frequency in question.

An inspection of the foregoing curves shows that, in general,

the effective antenna resistance is many times the apparent resistance of antennæ as ordinarily used, and that, therefore, the design of receivers should be materially altered in order to utilize to the best advantage the energy impinging upon the tree in the form of electromagnetic radiation. Except for very weak signals,

FIG. 10.



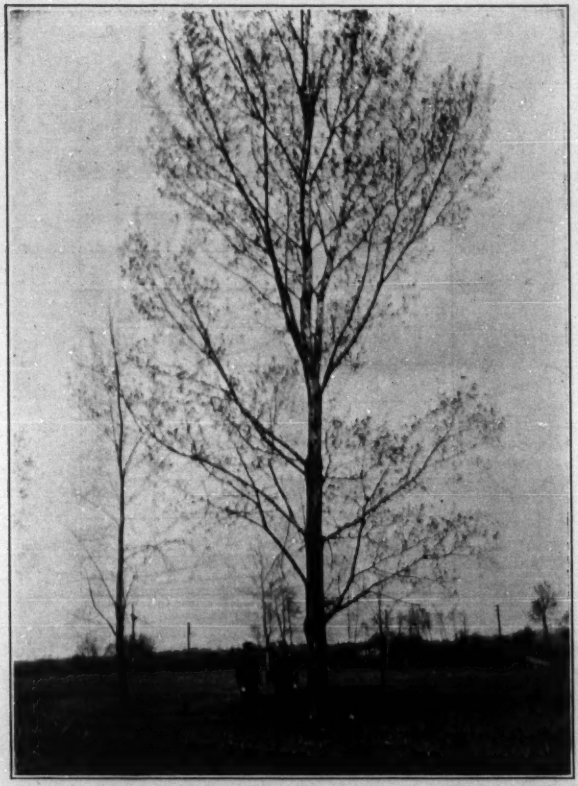
however, it is not necessary to utilize this energy to the fullest extent, so that receivers of present design may be used, and when so used, are responsive to any wave length of radiation.

Open-circuit Voltage.

The other quantity which serves to determine the characteristics of any antenna system as a receiver of electromagnetic radiation from a given sending station is the open-circuit electromotive force E. The determination of this quantity by measurement is a matter of considerable difficulty and so far has not

been accomplished with reference to the particular problem in hand. Apparatus of sufficient sensitiveness to accomplish the

PLATE III.



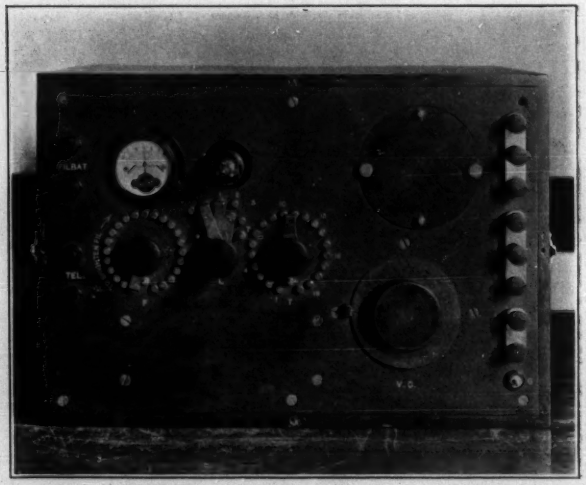
Large poplar tree used in audibility measurements. Average diameter 0.33 meters.

direct measurement of this electromotive force is not at present available to the art. Indirect methods may, however, be used,

and from them comparative results of fair accuracy may be expected. An outline of one such indirect method is given here.

The open-circuit voltage of the tree system as an antenna is to be determined for different heights of contact and for different frequencies. To be of use in determining the behavior of the antenna system, without reference to a particular sending station, this open-circuit voltage must be that for unit field strength of impinging radiation. This can be determined by dividing the

PLATE IV.



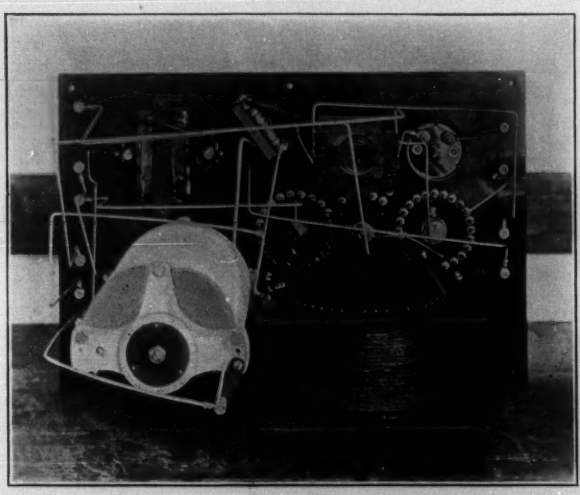
Front view of Signal Corps portable heterodyne receiver used for audibility measurements.

observed value of voltage by the calculated field strength set up by the particular sending antenna.

To make observations a simple form of antenna for which the open-circuit voltage can be calculated in terms of the field strength may be used, such as a simple vertical wire. After the apparent properties at the various frequencies which are to be used have been determined, connect in series with this antenna (also shunting it by a capacity to ground if necessary) such resistance

and capacity as to make its total constants equal to the apparent constants of the antenna whose open-circuit voltage is desired. Then arrange for the alternate connection of these two antenna systems to a receiving set and associated audibility meter. The readings of the audibility meter which give equal intensity of signals then correspond approximately to the square of the open-circuit voltages (Austin's Law for a Vacuum Tube Rectifier using a grid leak and a condenser). The open-circuit voltage of the simple

PLATE V.



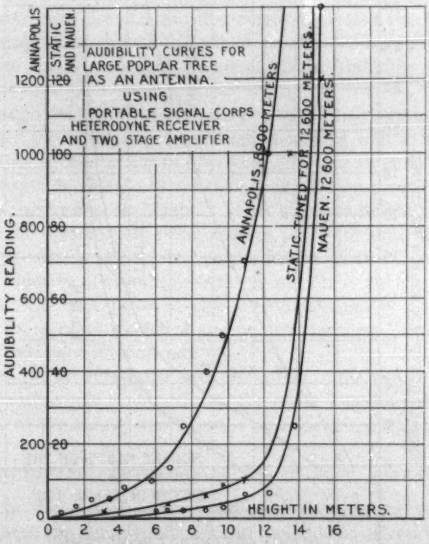
View of interior of Signal Corps portable heterodyne receiver used for audibility measurements.

antenna being calculable, the value of the voltage for the unknown system becomes known. If it is desired to eliminate from the calculations this law concerning rectification, the antenna may be loosely coupled to the receiving set and the coupling varied for the two systems until equal signals are received, thus eliminating the audibility meter—a device not at present very dependable. For equal signals the ratio of such coupling is inversely proportional to the open-circut electromotive force because of the fact that the

impedances of the two antenna systems were originally made equal.

From the field experiments made by Lieutenant Browning and Lieutenant Riner, Signal Corps, certain data are available giving the audibility of signals as received with a portable Signal Corps Heterodyne Receiver and two-stage amplifier connected to a large poplar tree as an antenna. Plate III shows the tree used. Plates IV and V show the receiving set.

FIG. 11.

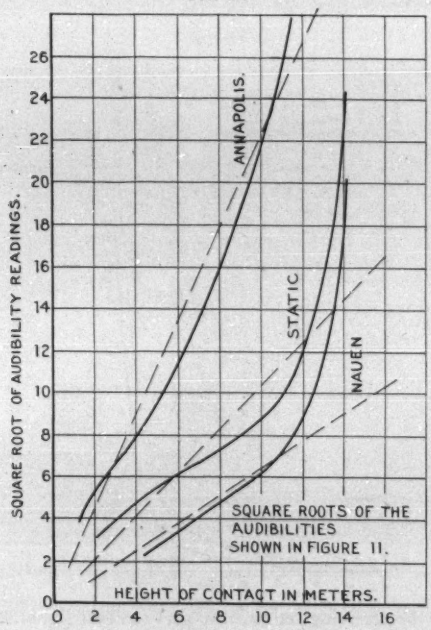


With the receiving set tuned to give the best signal strengths, data concerning the audibilities at different heights of contact were obtained. These data are illustrated by Fig. 11, in which audibilities are shown as functions of the height of contact. The wave lengths are indicated on the curves. Very great increase in audibility occurs at about twelve metres height (about two-thirds of the total height of the tree).

Since the audibilities are approximately proportional to the

square of the electromotive force applied to the receiving set used at a given frequency, it is instructive to consider the curves showing the square roots of the audibilities. Such curves are shown in Fig. 12, and, except for values above twelve metres in height, these curves are quite closely approximated by straight lines. Theory would lead to the conclusion that the open-circuit

FIG. 12.



voltage is a straight-line function of the height, and, since the receiving set was tuned to maximum sensitiveness for each reading so that the total reactance of the circuit was zero, the remaining quantity to which must be attributed the departure of these curves from straight lines is the variable (and in this case unknown) antenna resistance. In other words, it is suggested

that, had the total resistance of the antenna system been maintained constant by the insertion of series resistance of the proper value, the curves in Fig. 12 would approximate very closely to straight lines.

The trees on which the impedance measurements and the audibility measurements were made are practically equal in height, so that it is reasonable to suppose that similar phenomena would be observed in both. It is to be noted that the height at which the audibility curves show their sharpest upward trend, which is also the same height for which the square roots of the audibilities depart from the straight-line relation, is also the height at which the apparent shunt resistance r_p reaches a minimum value in Fig. 6, for the wave lengths involved in the audibility measurements.

Although the term " open-circuit voltage " has been introduced throughout the foregoing discussion, it will be well to recognize the fact that such a means of specification of an antenna's properties corresponds closely to means of expression already in use, that is to the " effective height." This effective height is proportional to the open-circuit electromotive force for unit field intensity. It is usually considered as the height of the centre of the antenna capacity above the ground plane. It is only in order to lead to a clear conception of any antenna system as a particular form of the general electrical circuit that the term " open-circuit voltage " has been introduced.

It is hoped to determine more definitely in the future, by some such method as has been outlined, the exact relation between the geometry of the tree system and the open-circuit voltage.

GONIOMETRIC METHODS APPLIED TO TREE ANTENNÆ.

One of the special lines of radio development caused by the war has been the application of radio methods to direction finding for military purposes. The Signal Corps has evolved and standardized certain sets possessing extreme compactness for the use of the mobile forces.

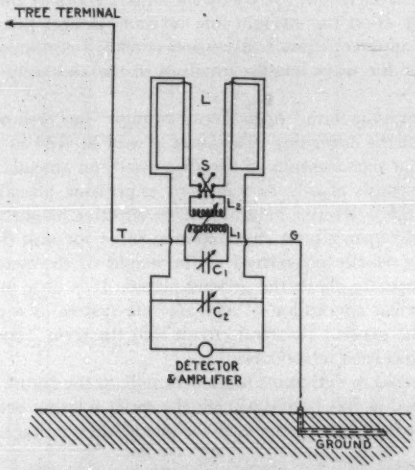
Under the intensive study of this subject, stimulated by the war, a large amount of technical information has been obtained which is now available for use and application to the purposes of peace.

Through the coöperation of F. A. Kolster of the Bureau of

Standards, who has specialized in this work for the Navy Department, some applications of these methods have been applied to tree antennæ.

Coil aerials of extremely small dimensions as compared with ordinary antennæ, may be effectively used for both long and short-wave long distance reception. It is therefore entirely possible to make use of such a coil aerial in combination with the tree system, without in any way detracting from the remarkable sim-

FIG. 13.



plicity of the tree system, for the purpose of obtaining the desirable feature of unidirectional reception or so-called "barrage" effect.

Coil aerials of very small dimensions as compared with the wave length received are nothing more nor less than ordinary inductance coils directly and magnetically exposed to the incoming electromagnetic wave, and may form the entire or the major portion of the inductance of a simple series resonant circuit. Such a circuit is shown in Fig. 13, consisting of the coil aerial L, the inductance L_2, and the capacity C_2. This circuit to which there is connected the detector and amplifier forms the secondary

receiving circuit of the system and is coupled inductively to the primary circuit L_1C_1 to which the tree and ground wires are connected at T and G.

The system is unique in that both primary and secondary circuits are directly exposed to the incoming wave. It is by virtue of this double exposure that the unidirectional characteristic of the system is obtained. In other words, both primary and secondary circuits are simultaneously operated upon by the incoming electromagnetic wave and by the proper adjustment of the linking coils L_1 and L_2, the effects produced in the secondary circuit may be entirely neutralized or accumulated. Switch S shown in Fig 13 is a reversing switch connected to coil L_2 which controls this neutralizing or accumulating effect.

Complete "barrage" effect was obtained with this system on stations such as New Brunswick, New Jersey; Annapolis, Maryland; Nauen, Germany, etc. This makes it possible, for example, to receive signals from San Diego, California, while the New Brunswick station is operating and using practically the same wave length as the San Diego station.

The coil aerials used in the experiments made with the system above described are but four feet square and therefore are located within the station, merely forming a part of the internal receiving apparatus and in no way complicating the simple tree system.

We have then a simple two-circuit receiving system requiring no extensive and costly outside aerial structure and have the following modern features:

a. Long distance reception at any wave length.
b. Direction finder giving not only the line of direction but the absolute direction.
c. Elimination of interference by virtue of the unidirectional characteristic or "barrage" effect.
d. Simultaneous reception of two or more wave lengths or of two similar wave lengths coming from opposite directions.

Heretofore, in existing operating stations the receiving circuits, of whatever nature, have operated primarily on the generation of alternating currents in the receiving antenna system, and because of this it has been necessary to tune the antenna system

itself to the particular frequency of the signals. In the experiments in tree telephony and telegraphy, we may rather consider that we employ an aperiodic system in the form of the tree itself, and make use of the resultant potential effects at the upper tree terminal of this antenna, selecting from this reservoir of all frequencies the particular frequency desired, by means of external receiving devices now known to the art.

In addition to the plates already described a number of others are included which show in a general way the equipment and apparatus used.

III. AFTERWORD.

Potential Earth-Terminal.—We may regard the metallic electrode rigidly driven into the living organisms of a tree, as described above, as a potential earth-terminal for the study of the potential distribution on the surface of the earth itself. It has been shown in these experiments that this metallic terminal intimately connected to the earth itself and a part thereof is subject to changes of potential representing the innumerable frequencies required by modern radio telephony and telegraphy as well as any other electrical disturbances which may occur on the surface of the earth or the atmosphere above the earth.

It has been also shown, as expected, that we can select from this composite one or more of the different frequencies by tuned electrical loop circuits suitably connected to this electrode and study each in turn at will just as color screens can select a particular component of white light. We may, indeed, by means of a highly insulated conductor bring this terminal directly to the laboratory and connect it immediately to the modern thermionic tube and amplify almost at will the particular effects we are studying. This tube is a powerful and new instrument of research for the modern physical laboratory. Has not the physicist therefore in this electrode a means of studying in detail atmospheric and earth electrical disturbances of absorbing interest and far-reaching importance?

In short, the radio art as a whole has attracted some of the best equipped physicists in each country as perhaps no other practical engineering subject of recent years has done, with the result that the methods and means of the radio art are now immediately applicable and available to the physical laboratory for the study of the fundamental problems of the earth itself as a charged sphere.

For four years, under the stimulus of the World War, the efforts of engineers have been expended in producing instrumentalities for the generation and reception of radio signals and there has been little time to coördinate and assimilate the information gained into a better understanding of the ether mechanism for the transmission of electromagnetic waves through space, over the surface, or through the earth itself.

In the language of the modern captain of industry, physical theory is a temporary "corporation policy" rather than a fixed creed. Nevertheless, the modern specialist in science has, from the very nature of his intensive efforts, assumed what might be called a "polarized" attitude of mind toward the particular problem in hand.

The physicist and engineer, accustomed to deal with inanimate material, is here confronted with the employment of living vegetable organisms of growing trees. From the moment an acorn is planted in fertile soil, it becomes a "detector" and a "receiver" of electromagnetic waves and the marvelous properties of this receiver, through agencies at present entirely hidden from us, are such as to vitalize the acorn and to produce in time the giant oak. In the power of multiplying plant cells, it may, indeed, be called an incomparable "amplifier."

From this angle of view, we may consider that trees have been pieces of electrical apparatus from their beginning and with their manifold chains of living cells are absorbers, conductors, and radiators of the long electromagnetic waves as used in the radio art. For our present purposes we may consider, therefore, a growing tree as a highly organized piece of living earth to be used in the same manner as we now use the earth as a universal conductor for telephony and telegraphy and other electrical purposes.

All through the ages there is shown in literature a feeling of reverence, sympathy and human intimacy with trees. It is significant that this practical thing possessing utility and natural strength, architectural beauty of design, and endurance far superior to artificial structures prepared by man, should be able yet further to minister to his needs.

WAR DEPARTMENT, WASHINGTON, D. C.,
Office Chief Signal Officer,
April 21, 1919.

Cadmium a Substitute for Tin in Solders. ANON. (*U. S. Geological Survey Press Bulletin No. 407*, May, 1919.)—The large quantity of tin used in making food containers for rationing the American and Allied armies, combined with the lack of shipping and the loss of several cargoes of tin, produced a critical scarcity of tin in this country and led to government control of its distribution as well as to a campaign for its conservation. One method of saving tin is to substitute cadmium for it in solder. In the last year of the war the government and certain large concerns began experiments with cadmium solders as a means of saving tin. The results of these experiments were promising, but the demand for tin decreased, and the armistice was signed before cadmium solders became widely used. Cadmium was used by European nations during the war for some strictly military purposes, but little exact information is available to show those purposes.

The first of the belligerent nations to make large use of cadmium as a substitute for tin in solders was Germany, which from the beginning of the war was cut off by the blockade almost entirely from the world's sources of tin. About 600 tons of cadmium accumulates annually in this country as dusts and residues, by-products of the lead and zinc industries, and from these by-products about 100 tons of metallic cadmium is recovered. If all the cadmium dusts and residues were treated the output of metallic cadmium would be small in comparison to the 19,000 or 20,000 tons of tin annually used in this country in solder, even if due allowance is made for the fact that one pound of cadmium can replace from 3 to 5 pounds of tin.

The Inflammability of Aluminum Dust. A. LEIGHTON. (*U. S. Bureau of Mines, Technical Paper 152*, January, 1919.)—As prepared, the aluminum dust of commerce is finely divided aluminum metal with a coating of oil, usually stearine or some similar material. This coating evidently serves to prevent oxidation in air and to protect the metal particles from the action of moisture, as it is stated that the product loses its lustre if no oil be added. Aluminum dust is so light that it is easily blown about a room, and as the workmen seldom take precautions to prevent this the workrooms are soon coated with the dust. Evidently all apparatus should be inclosed to prevent loose powder from being blown into the air. Although experiments do not show the exact conditions under which an ignition of the aluminum dust is obtained, they do show that it may ignite at temperatures even lower than those necessary for the ignition of 200-mesh standard Pittsburgh coal dust; also more heat is needed to ignite aluminum dust. The dust used in the tests was a commercial product labelled "aluminum bronze."

OIL-SHALES.

BY

DEAN E. WINCHESTER.*

Geologist, U. S. Geological Survey.

It has been said, and probably said on good authority, that the great world war was won by petroleum, and we are all more or less familiar with the phenomenal growth of the gigantic industry which has proven itself capable of supplying not only the demands of our own military activities but in part those of our allies and at the same time furnishing the fuel for the countless motors and engines used by the people of the United States in commercial and pleasure pursuits. A glance at the figures showing the relation of the amount of petroleum consumed each year to the amount produced reveals the startling fact that the consumption has been rapidly approaching the production, and since 1915 it was even necessary to actually draw on the reserves in storage in order to meet the increased demands, and this while our oil men were straining every nerve to increase the output of petroleum both by discovering new fields and by developing to the limit the proven areas. The newly discovered fields have given us an increased production, but the total amount of petroleum derived from these fields has been insignificant in comparison to the total needs of the country. Is it any wonder then that men and companies are asking if it is not possible for the oil-shales of the United States to give us relief? After spending nearly five years in studying the oil-shales of the western part of the United States I am thoroughly convinced that the day is not far distant when these very shales that the cattle men and farmers of the Rocky Mountain region have sworn at so often because they make neither good farm land nor good range, will be yielding oil in sufficient amount to prevent the rapid decline in our total oil production, which is imminent if no new source of petroleum is developed. There seems to be every indication that in the near future (perhaps within ten years) there will be established in Colorado and Utah an industry for the mining and distilling of

* Presented at the Stated Meeting held Wednesday, February 19, 1919, and published by permission of the Director, U. S. Geological Survey.

oil-shale which will rival in size any of the mining or manufacturing industries now developed in the United States. At this very time there are at least seventy-five companies organized for the purpose of manufacturing oil from the shale, and many of these companies are contributing considerably towards the research that will ultimately place the industry on a firm foundation.

Bright as the future seems to be for oil-shales it must be remembered that before a profit-paying industry is established large sums of money must be expended in the development of processes and practical machinery for extraction of the valuable products of the shale. The cost of producing shale-oil must include such items as mining, transportation of the raw shale from the mines to the retorting plant, crushing, retorting, condensing, manufacture of ammonium sulphate and disposal of the spent shale, which will weigh at least 60 per cent. as much as the shale as it comes from the mines and will probably be only slightly less bulky.

Unfortunately the word "oil-shale" brings to the mind of the uninitiated visions of wealth similar to the wealth that has come to those oil men who have been fortunate in making strikes in the oil fields. The oil-shale industry is to be more like the great Bingham, Utah, copper district, where thousands of tons of low-grade ore are handled daily and where each ton yields only a small profit. Enormous capital will be required to establish a profitable oil-shale plant, and men with small means should be very careful before investing it in oil-shale to be sure that the company in which they invest has ample capital and good, sound, thorough men at the head who are willing to spend large sums in experimental work before returns are forthcoming.

Several years before the first discovery of petroleum in 1857 "*coal-oil*" was being made from cannel coal and black shale in the eastern part of the United States, and it is reported that at the time of the first discovery of petroleum sixty companies had been organized and many of them equipped with the necessary machinery for making oil from the rocks, but the newly discovered fuel proved so cheap that all these attempts at manufacturing oil were abandoned. Recently the increased demands for petroleum and the high prices paid for gasoline, fuel oil, etc., have revived the idea that it may be both practical and profitable to distil oil from rocks. This time attention is being directed largely toward the rich oil-shales of the Rocky Mountain States.

In order that the subject of oil-shale may be rightly understood it is essential to have a clear idea of the difference between an oil-shale and an oil sand. The petroleum of to-day is coming largely from oil sands, but it may not be amiss to prophesy that it will not be many years before oil-shales will furnish oil in large quantity. An oil sand is a more or less porous rock between the grains of which the oil is entrapped and from which the oil may be extracted by solvents or mechanical means or from which oil will flow when the sand is penetrated with the drill. Oil-shale, on the other hand, is a very fine-grained and compact rock which contains practically no free oil but which does contain an abundance of partly decayed and bituminized organic matter from which oil can be manufactured by simple distillation processes.

Practically all oil-shale is tough and hard to break, and some of the thin-bedded varieties are remarkably flexible. All oil-shale is thin-bedded, although some of the beds weather into massive ledges, in which case the thin-bedded character is evident only after the shale has been heated and the oil driven off. On the exposed surfaces oil-shale weathers to a bluish-white color, but the weathered surface is only skin deep, so to speak, for usually within less than an inch from the outside the shale is unaffected and has the characteristic dark-brown or black color; the darker the color the richer the shale. When freshly broken, oil-shale gives off an unmistakable odor of petroleum, but this quickly vanishes, so that within a few minutes after the rock is broken the asphalty odor has entirely disappeared. Many of the richest shales of the Green River formation of Colorado, Utah, and Wyoming have a peculiar waxy or velvety lustre and resemble in a way cannel coal. Still other and equally rich shales are dark brown, and in the case of the rich oil-shale from near Elko, Nev., the rock is yellowish-brown and lustreless. Most of the oil-shale beds are composed of alternating dark and light colored laminæ with the relative richness of the bed depending on the preponderance of the darker colored material. Good oil-shale will burn with a sooty yellow flame when it is ignited with a match. In the region where the oil-shales outcrop, campers and cow men very often use the shale for fuel in their campfires, and in some places I have even seen the rock used in the stoves. This latter use, however, is not very satisfactory on account of the great amount of ash which oil-shale contains. Late in the fall of 1918 my little party was working near the great cliffs of oil-shale in northwestern

Colorado when much to our dissatisfaction the weatherman decided to give us a week of rain, and as a result everything, even the firewood, was wet and there was no coal within twenty-five miles. A happy thought, and after a little coaxing a fire was kindled and blocks of oil-shale which lay all around on the ground were piled over it. Very soon we had a rousing fire, even if it was sooty, and those rocks burned furiously for at least three hours and in the end the camp washing was done.

Valleys near the outcrop of the oil-shale are always strewn with the boulders of shale which have been broken from the ledges at the outcrop, and in many places these large angular pieces have been carried miles from their original resting place without disintegrating in the least, for weather has very little effect upon the oil-shale. The story is often told in the shale regions how a certain rancher built a new cabin and made the fireplace and chimney out of the blocks of shale which he found strewn about over his fields. The very first time that he made a fire in the fireplace his house was destroyed, and not even the chimney was left standing, for that, too, burned, and there remained only a bed of soft ashes after the flames had been quenched.

Oil-shale is much lighter in weight than coal, and the lighter it is the more oil can be distilled from it. Coal with an ash content of 10 per cent. is considered pretty poor fuel, but the oil-shale which I just described burns furiously when once started and yet has 50 to 70 per cent. ash and therefore could not be used as fuel satisfactorily.

The Green River formation contains the richest and most extensive beds of oil-shale known, but not the whole formation is oil-yielding. Rich oil-shale is interbedded with lean or barren shale or in a few places with oölite and sandstone, and because of its resistance to the weathering agencies beds of rich oil-shale ordinarily project beyond the rest of the rocks which are present in the cliffs. Along the south side of the great Uinta Basin in Colorado and Utah for a distance of 150 miles or more there are beds of oil-shale thick enough to mine and rich enough to warrant the establishment of an industry of immense proportions; in fact, nearly 4,000,000 acres in this region have been classified by the Government as land valuable for its oil-shale. The greatest thickness of rich oil-shale beds is in the eastern third of this great area, and in the part of the field near De Beque and Grand Valley, Colo., and Watson, Utah, there are beds of rich shale aggregat-

ing more than a hundred feet, and much of this shale is capable of yielding more than a barrel of oil to the ton of shale.

Oil-shale beds in most places lie nearly horizontal, much as the coal beds in the western part of Pennsylvania, but different from the coal in that oil-shale beds outcrop high up on the sides of great mesas 2000 to 3000 feet above the valleys. Because of this, when our engineers begin to work the shales they will have to install long and expensive tramways to bring the shale down to the elevation of the distillation works, which will necessarily be located in the valleys near water and transportation.

The shales of the Green River formation were all laid down in fresh water lakes in which grew great masses of vegetation and into which the pollen and leaves of the higher plants were washed and blown by the winds. Large numbers of insects swarmed the air in those days and their bodies were buried in the slimes and mud at the bottom of the lakes, and these shale beds now contain an abundance of excellently preserved fossils. During the last two field seasons considerable time has been spent studying these records of the life that thrived when our oil-shales were being made. The fossil collections now include beautifully preserved beetles, flies, mosquitoes, bees, leaves of all kinds, fish skeletons, and even bird bones. And in addition to these fossils which are visible to the naked eye the microscope brings to light an immense variety of tiny organisms, many of which are easily identified but others of which are as yet not understood. The richer oil-shales contain an abundance of vegetable material, including such types as ferns, fungi, bacteria, algæ, and pollen, perhaps the most remarkable of these being the algæ. It is difficult to imagine under what conditions such delicate forms as the water trough slimes could be imbedded in mud and then the mud become hardened to the tough shale as we find it to-day and still have the cellular form of these soft plants preserved. This is one of the wonders of oil-shale. The immense amount of organic material in the rich oil-shale and the relative absence of such material in the leaner shales may be a mere coincidence, but when it is realized that it is practically impossible to extract any oil from even the richest shale by any means except heat, then it seems that the oil must be made by the destructive distillation of the organic material and that in all probability the larger part of the oil comes from the vegetable matter in the shale, and perhaps most of it from the lower forms of vegetation such as the algæ.

The richest oil-shales in the United States belong to the Green River formation of Eocene age and are to be found in Colorado, Utah, and Wyoming, but these are by no means the only shales which will yield oil when distilled. The Devonian black shales, for instance, which underlie great areas in the eastern part of this nation, are in most places oil-yielding, but the amount of oil that they will yield may be too small to allow their commercial development. Only a very rough reconnaissance study of these shales has been made, and it is not at all certain that more careful search in Indiana, Ohio, New York, Pennsylvania, Kentucky and Tennessee will not disclose areas where the shales of this age are sufficiently rich to warrant their being worked. In general the oil-shales of these older geologic formations have the same characteristics as the oil-shales of the Green River formation.

Cannel coals are as a rule capable of producing a goodly quantity of oil when subjected to distillation, and where the cannel coal is so high in ash as to prevent its use as a grate fuel it is well worth while to consider the mining and distilling of such material for its oil and ammonia values. The bony coal which is found in connection with some of the bituminous coals may also be worthy of consideration, although this kind of material will probably yield very heavy oil or tar when distilled.

In western Montana certain dark shales belonging to the older formations (Upper Paleozoic age) have been found to yield a moderate amount of oil when distilled, and in addition some of these shales contain phosphate, an element which is much in demand for its fertilizing value. If the phosphate in these shales is in some form that can easily be made usable it is quite possible that these shales can be treated jointly for their phosphate and oil values at a profit, but it is certain that the cost of operating them for their oil alone will be prohibitive.

A broad field is open to those interested to determine what substances there are in the United States which are capable of yielding liquid oil products when distilled. The Germans have for many years been distilling lignites, and perhaps our own lignite of North Dakota and Montana, as well as Texas and the Gulf Coast States, will find a market through this channel. It is certain that many of the "fatty" lignites are worthy of investigation with this in view. Experiments are already being carried on to determine the possibilities of the North Dakota lignites as oil producers.

Organic deposits like oil-shale and coal contain a considerable percentage of nitrogen, and the successful development of oil-shale may depend largely upon the economical recovery not only of the oil but the nitrogen of the shale. Recent analysis of nearly two hundred samples of oil-shale has uncovered the fact that American oil-shale is different from the Scottish oil-shale in that in the oil-shale of the Green River formation the percentage of nitrogen increases with the richness of the shale. It is reported that in the shale being mined in Scotland the shales richest in oil are poorest in nitrogen. Although the percentage of nitrogen in the oil-shales of the Green River formation of Colorado is not as great as the percentage in ordinary coal, the recovery of this valuable element will add only a small cost to the process of treatment in proportion to its value.

We in America have never been driven to the development of our natural resources to the extent of many of the other nations of the globe. In Japan, for instance, the people are forced to artificially terrace the rocky mountain sides in order to make room to grow sufficient farm and garden products to maintain the population of the islands. In Scotland no petroleum has been found, and the people long ago perfected processes for extracting oil from the oil shales of their territory, and for more than sixty years there has been an industry in Scotland which has supplied much of the oil needed for its industries. In each of these places the people have risen to the occasion and have devised means to provide the necessities from the materials at hand. Records show that in Scotland the shale treated averages only about twenty-four gallons (little more than half a barrel) of oil per ton of shale. What the Scot can do with this medium grade oil-shale we surely can do with a shale which will yield perhaps twice as much oil if not more.

Within the past five years numerous individuals and companies have devoted a great deal of attention to the oil-shales of the western part of the United States. Much of the more favorably located land has been filed on as mineral land under the mining laws of the nation and in a few cases the Government has actually been asked to transfer the patent to this land to private individuals. Several of the companies are carrying on extensive chemical and engineering research looking toward the development of efficient and practical processes and machinery for getting the oil and other valuable products from the shale, and at the

present time there are at least a score of different processes proposed and partly perfected for the distillation of oil-shale. Many of these are doubtless destined for discard not because they fail to produce the shale-oil, but because they either will not produce the right kind of shale-oil or the oil produced will cost more than it can be sold for.

The United States Bureau of Mines is conducting experiments and investigations looking toward the utilization of the oil-yielding shales of the western States, but it will necessarily be some time before the results of this work can be published.

During my own field studies of the oil-shale for the U. S. Geological Survey in the last five years I have found it of great value to the work to make distillation tests of samples of oil-shale in the field, and for this purpose I have carried with me a small apparatus in which I could heat a weighed amount of crushed shale and condense the vapors which were formed and measure the resulting distillate. This apparatus consisted simply in a small (half-pint) iron retort connected to a simple all metal water-cooled condenser. Heat was furnished by a small gasoline plumber's torch, and the distillates were measured in a glass graduate. Crude as was this field apparatus I have found that it was possible to vary to a remarkable degree the kind of oil that would be derived simply by changing the quantity of heat used, and no doubt if it had been possible to vary other conditions pertaining to the distillation, such as pressure, etc., additional variations in the product would have resulted. For instance, if I rapidly increased the temperature of the shale till it was heated to red heat I got a very different character and quantity of oil than that received when early in the treatment I raised the temperature very slowly. If a slight manipulation of the conditions of heating in this crude apparatus will make such a difference in the character of the product, then it seems that until we have shale-oil produced in a commercial plant there is little value in having a chemist determine carefully the characteristics of shale-oil. This is the more important when it is realized that no two of the many processes that are being proposed for oil-shale distillation are designed to subject the shale to the same conditions. As soon as there is in this country a commercial plant for the production of shale-oil we can find out what shale-oil is and how it compares with the petroleum of the various oil fields. Roughly, I believe that it is safe to prophesy that the shale-oil of the future will yield on

refinement products that are quite similar to those that are manufactured from ordinary petroleum, but until we know what the shale-oil is and what it will produce it is obvious that no one can state in more than general terms what will be its value in dollars and cents. I will not be at all surprised to see products not now produced from oil-well petroleum developed commercially from shale-oil.

The shale-oil that has been produced in the Scottish oil-shale industry is a thick green oil which at ordinary temperatures has much of the consistency of vaseline, and if the oil that is to be produced from our own oil-shales is similar to that made in Scotland we must devise other means than pipe lines for transporting it from place to place. Fractional distillation of the shale-oil that was produced in the small testing apparatus used in my own field examinations gave about 12 per cent. gasoline and 35 per cent. kerosene, with as much as 9 per cent. paraffin. These figures are not at all complete or final but they serve to give us a general idea of the character of shale-oil.

In the distillation of oil-shales there are four primary products, namely, oil, gas, water and spent shale. The character of the oil will vary somewhat with the character of the original shale, as, for example, the shale-oil from the shale near Elko, Nev., is much higher in paraffin than most of the shale-oil that has been produced by the same methods from shale of the Uinta Basin in Colorado and Utah, but the greatest differences that will be found in the shale-oils are likely to be due to the conditions under which the shale is distilled.

Gas will be made in the retorts which will not be condensed to oil. This will contain ammonia, which can easily be extracted and converted into commercial ammonium sulphate, which is valuable as a fertilizer. The average nitrogen content of shales of the Green River formation yielding more than 15 gallons of oil per ton is theoretically equivalent to about 50 pounds of ammonium sulphate per ton shale, and, of this, commercial practice should recover at least 60 per cent., so we may expect that our shales will yield at least 30 pounds of ammonium sulphate from each ton of shale distilled.

Nearly all rocks contain water, and oil-shale is no exception, and in their distillation for oil the water will, of course, be vaporized and condensed along with the oil. It has been found in the Scottish practice that the recovery of nitrogen from the shale is

assisted by the addition of water or steam to the shale while it is being heated, and if this is found advantageous with the American shales the amount of water which is discharged from the condensers will, of course, be large. This water should contain most or all of the ammonia which is formed in the retort by the decomposition of the nitrogenous compounds in the shale.

One of the great problems connected with the recovery of the valuable products from oil-shale will be that connected with the ash or spent shale. In the small testing apparatus some of the richer shales have been found to fuse and slag together and their removal from the retort thus made difficult. In the larger retorts it may be found that the injection of steam into the heated shale within the retort will help prevent this caking as well as help to secure the maximum recovery of the nitrogen of the shale, or it may be found necessary to agitate the shale while it is being treated, or even mix the rich shale with leaner material. These are some of the problems to which the chemist and engineer must give attention. Furthermore, it is to be expected that the satisfactory operation of a given apparatus using one type of shale will not constitute proof that the same machine will produce equally good results from all oil-shale. For instance, the methods and apparatus found efficient for the mining and treatment of the oil-shale from near Elko, Nev., will doubtless have to be greatly modified before they will produce good results when used in connection with the shales of northwestern Colorado.

So far as at present known there seems to be little proof that valuable substances remain in the spent shale, and since a plant which is built to handle 1000 tons of raw shale per day must handle and dispose of probably 600 tons of waste material whose bulk is only slightly less than the original shale, the problem of the disposal of this spent shale is one which must be solved before the plant is established, as ample dumping ground must be available. It has been suggested that this waste might contain potash or phosphate, but none of the samples so far analyzed by the Geological Survey have been found to contain sufficient soluble potash to warrant a quantitative determination, and only the black shales of the Phosphoria formation of western Montana have been found to have a high percentage of phosphate in combination with oil-yielding ability.

Reports that oil-shale was rich in gold, silver, lead, zinc, platinum, etc., have been circulated and have attracted much attention,

but to anyone who is familiar with the conditions under which such metals accumulate the chances seem very small for finding commercial quantities of shale which will yield values in these elements. I have been informed that in a large number of samples assayed by the University of Colorado some of these metals have been found, but in no sample was the combined value for the metals found to be much more than $1 per ton.

Chemists experimenting with the oil-shale and the shale-oil produced from them are making many and varied products—rubber substitutes for use in automobile tires, gaskets, and other places; beautiful dyes and powerful explosives; paints and many other interesting things, but the great question is not what is it possible to make but what can be manufactured profitably. Again we must wait for answer till shale-oil is being produced commercially.

Like all new enterprises there are any number of ideas as to the correct way to treat oil-shale to get the best results. I have had the privilege of seeing the designs of many of these processes and of seeing the machinery installed for a few of them, and I will give a brief outline of the principles of those which I have seen, more to illustrate the widely divergent ideas than to give details of the processes.

One of the first plants erected and tried out on the western oil-shale consisted of a metal tube about 30 feet long and a foot in diameter set in a brick fireplace and inclined at an angle of about 10° to the horizontal. Partially crushed shale was fed into the tube at the lower end and carried slowly upward through the retort by a screw conveyor and discharged at the upper end. Heat was applied to the retort about midway between the ends, so that in traveling the length of the tube the shale was gradually heated to red heat and then gradually cooled till it could be easily handled at the discharging end. The volatile products are removed by slight suction at the intake end of the retort.

A second process consists in a metal chamber or retort, cylindrical in form and standing on end. Raw shale is fed into the top and passes downward and at the same time the temperature is increased. The lighter hydrocarbons are supposed to be distilled off from the shale in the upper part of the retort and the heavier hydrocarbons used for fuel in the lower end of the same retort where the half-spent shale is burned.

One retort which is being installed by several companies with properties near De Beque, Colo., consists of an inclined trough with cover, set in a brick oven. The cover is equipped with numerous exit tubes through which the volatilized products of the distillation are allowed to escape to the condensers. Finely crushed shale is fed into the upper end of this retort and conveyed down by a mechanical agitator. The maximum heat is applied to the lower end of the retort, so that the temperature to which the shale is subjected increases as the shale travels down the 30-foot long retort. The numerous exit tubes are supposed to allow partial fractionation of the oil as it is formed.

Still another distilling apparatus which has been tried out consists of three iron tubes placed horizontally one above the other and communicating at alternate ends. Shale is fed into the upper tube and conveyed through the three consecutively by screw conveyors. Each tube is provided with exit for the gases evolved in it and these are condensed separately, so that at least theoretically there is a three-part fractionation of the crude shale-oil as it comes from the retort. Heat is applied to the lower tube and conducted beneath the other tubes, so that the least amount is applied at the point nearest where the shale enters the system.

The retorts now used in Scotland are the growth of many years of experimentation. The earliest apparatus used there consisted in horizontal tubes, but these were soon discarded in favor of the vertical tubes, and at present the principal retorts consist of tall cylinders somewhat larger at the bottom than at the top and provided with no force but gravity to convey the shale from the top down to the point of exit after it is freed of its oil-forming substance. Some of the older vertical retorts were provided with internal agitators, but these were sooner or later discarded because the operation of metal parts in the highly heated chamber gave endless trouble. Heat is applied externally to the retorts, and the fixed gases from the shale provide ample fuel for the heating of the retorts. Gases are conveyed from the retorts into large air-cooled condensers consisting of many vertical tubes or pipes. After this such gas as is not condensed is scrubbed for ammonia by washing with water and for additional naphtha by washing with heavy oil. In the Scottish industry it has been found that the permanent gases are more than sufficient to heat the retorts.

Two processes are being perfected in America each of which

uses modifications of the Scottish retorts, and each of these will use condensers of special design and radically different from the simple air-cooled condenser used in Scotland.

At least one retorting system proposed for our American shales embodies the principle of removing the gas from the centre of the shale chamber on the theory that this will prevent to a maximum degree the cracking of the oil into undesirable gases. In this machine heat is applied externally to the large cylinder containing the shale. In the middle of this cylinder there is a perforated exit pipe through which the gases are drawn off and sent to the condensers.

One of the most complicated retorts designed for the distillation of oil-shale comprises eight communicating chambers, four of which are provided with a hearth attached to a revolving shaft and four of which are furnace chambers into which the heat is applied. These heat and hearth chambers alternate one above the other; the shale entering the topmost chamber first is carried by a rotating agitation system across the first hearth and then consecutively to the second, third and fourth, the temperature being higher in each chamber. The vapors are removed from each chamber separately and condensed, so that the oil is partially fractionated as it comes from the retort.

Oil-shale, as has been said, is a rock from which the oil and other products may be distilled, but before the shale is ready to retort it must be mined like coal and crushed. Within the areas in the Rocky Mountain States that are underlain with rich oil-shale there are many small tracts where the shale is sufficiently close to the surface to be mined with a steam shovel, but most of these tracts are remote from transportation and therefore may not be used in the first stages of the developments. We must therefore now look carefully to the conditions that will affect the methods and expense of underground mining. The shale lies in "blanket form" like coal, and in most places the beds are practically horizontal, so that none of the difficulties incident to the mining of steeply tilted beds such as are met in the oil-shale industry of Scotland will be encountered. The rich oil-shale beds are usually overlain by beds which will not be affected by weather, so that little trouble is to be expected with roof. The shale may be harder to mine on account of its toughness, but machinery will be developed which will cut and drill the rock without difficulty. The

cost of mining shale will be at least as great as the cost of mining coal in the same region.

After the shale is mined it must be transported to the retorts, and because of the fact that the shale beds outcrop high on the sides of mesas, in some places 2500 feet above the sites which must be chosen for the retorting plants, this transportation will necessitate the installation of tramways in some cases a mile in length. Then the rock must be crushed to the appropriate size before it is ready to go to the retorts. The fineness to which the shale will be crushed depends upon the process that is adopted for its treatment. One of the methods proposed requires that the shale be crushed to a powder; others propose to handle shale almost as it comes from the mine. For the task of crushing the shale it may be necessary to design and construct crushers of special model, as there will be a tendency for the shale to gum and pack in the crusher.

At the present time there is no exact or satisfactory information regarding the cost of any of the phases of this new industry. The installation of a tramway system capable of delivering shale to a commercial sized plant will probably mean the expenditure of $15,000 or $20,000, and the crushers will cost money to install as well as operate. The cost of a retorting system has been estimated at from $300 to $2500 per ton of shale to be treated per day, depending on the system that is to be used. The cost of operating the apparatus after it is installed is, of course, as uncertain as the original cost of the plant because of the undeveloped stage of the machinery. The following figures showing the pre-war costs of the Scottish industry can for want of better be considered as the best figures available. The installation of a large Henderson retorting plant before 1909 was quoted as about $350 per ton daily capacity, and the cost of operation, including mining, crushing, with the production of crude shale-oil and ammonium sulphate, was $1.86 for each ton of shale handled. After this it remains for the shale-oil to be refined before the maximum value is obtainable.

In conclusion, therefore, it is evident that we have material in abundance which is capable of furnishing the oil that we need for the future operation of our motors, but before this raw material can be used it must be dug from the earth, then it must be treated in elaborate and expensive apparatus which is as yet

unperfected. The successful oil-shale plant will necessarily be one capable of treating at least 1000 tons of shale per day, for it will be possible under efficient and economical management to realize only a small profit from each ton of rock handled. Before the oil-shale industry is on a profit-paying basis much time and money are bound to be spent, and a great many people who have been led to believe that the oil-shale industry will rival the gusher oil well as a money maker will be disappointed. However, I can see no other way but that eventually the oil-shale of Colorado, Utah, Wyoming, and perhaps some of the other States, will be made to produce oil, fertilizer, and profits in large quantity.

Machine Tools. A. HERBERT. (*Proceedings of the North-East Coast Institution of Engineers and Shipbuilders*, March 11, 1919.)—Probably in the potter's wheel is to be found the first germ of the machine tool itself. From producing by the aid of a rotating spindle cylindrical forms in plastic material, it is no great step to the invention of the first crude woodworking lathe, but the modern machine tool is a product of comparatively recent times, and its development coincides very closely with that of the steam engine. To Maudslay on the one hand, and to Whitworth on the other, we, as users of machine tools, owe the greatest debt. Maudslay is credited with the production of the first slide rest, and it was Whitworth who, by his accurate plane surfaces, and by his wonderful progress in exact measurements, became the father of mechanical accuracy. Given the ability to produce reasonably accurate cylindrical and plane surfaces, and given the slide rest, the evolution of machine tools became simply a question of time.

The lathe undoubtedly was the first real machine tool. It is of all machine tools even to-day the most important and the most universal, and in fact, a lathe with appropriate attachments is capable of performing, after a fashion, most of the machine shop operations. The shaping machine, or "iron arm" as it was originally called, was also very early in the field, and from these two primitive types all the modern highly specialized machine tools have gradually been evolved. In direct line of descent from the lathe, we find the milling machine, the boring machine, the drilling machine, the screwing machine, the capstan lathe, the automatic screw machine, the automatic turning machine, the universal and plain grinding machine and the boring and turning mill. From the shaping machine are descended the slotting machine, the planing machine and the surface grinding machine. Each of these various machine tools has been taken in hand by

innumerable designers and developed into specialized types to meet the constant growth of demand—until to-day the machine tool family is enormous, both in range and in variety.

It is well that we should acknowledge our indebtedness to the United States for much of our progress in machine tool production and in workshop methods. American tool builders were stimulated to a great extent by the high level of wages. In this country wages for many years were at a comparatively low level, and British employers therefore did not have brought home to them the necessity of employing labor-saving machinery in anything like so forcible a manner as was the case in America. Repetition work was first seriously developed in the manufacture of small arms and of sewing machines. As soon as the possibilities of repetition work were realized, an immediate impulse was given to the improvement of machine tools and of measuring appliances and jigs and fixtures. In England the early importation of American machine tools soon demonstrated that there was a market there for machinery of this class, and their gradual introduction among the more refined industries, had a valuable educative effect both on machine tool users and on the English machine tool trade.

The discovery of high-speed tool steel marked an epoch in machine tool design. It was indeed startling to find one's whole basis of thought completely upset. For years the limiting factor in the metal moving capacity of machine tools had been the endurance of the carbon steel cutting tool, which failed by softening and losing its cutting edge whenever heated by the friction of the cut sufficiently to draw its temper. The new self-hardening steels at once changed the limiting factor to the machine tool itself, for it became evident very soon that existing machine tools did not possess either the power or rigidity necessary to get from the new steels the results that they were capable of giving.

The immediate result was the scrapping of machine tool patterns throughout the country, and the production of new designs embodying much greater weight and stiffness, accompanied with enormously increased power. A further development was a radical change in headstock design. It was soon evident that existing designs of lathe headstock failed to give the power required at the high speeds necessary to utilize the cutting capabilities of high-speed steel. Ideas of power, convenience, safety and quick-changing facilities spread very rapidly through the whole range of machine tool design, and were applied not only to main drives but to the feed motions. Comparatively recently the attention of designers has been directed towards relieving the operator of a good deal of the laborious work involved in moving saddles and other elements of machine tools; and in modern machines power operated adjustments are becoming standard practice on all the heavier types.

HOW THE NITROGEN PROBLEM HAS BEEN SOLVED.* †

BY

HENRY JERMAIN MAUDE CREIGHTON,

Department of Chemistry, Swarthmore College.
Member of the Institute.

VI. THE OXIDATION OF AMMONIA.

Since, with the exception of the arc process, all methods for the fixation of atmospheric nitrogen yield products which are readily converted into ammonia, its oxidation to nitric acid is one of the most important phases of the nitrogen problem. Although it was discovered in 1830 by Kühlmann that ammonia could be oxidized in the presence of platinum, it was not until the process was developed by Ostwald in 1902 that it became of technical importance. During the past few years various methods have been developed which effect the direct oxidation of ammonia by air in the presence of a catalyst.

OUTLINE OF THE PRINCIPLES UNDERLYING THE OXIDATION OF AMMONIA.

When a mixture of ammonia and air is allowed to flow through a heated catalyst (sometimes called the "burner"), nitric oxide is formed, in accordance with the equation:

$$(27)\quad 4NH_3 + 5O_2 = 4NO + 6H_2O + 220{,}000 \text{ cal.}$$

The oxide produced by this reaction can then be converted into nitric acid in a manner similar to that previously described under arc processes.

At low temperatures little or no nitric oxide is formed, but as the temperature is raised the rate of oxidation increases very rapidly, reaches a maximum at about 750° C., and then rapidly decreases, owing to the decomposition of the ammonia into its constituents. This change is shown graphically by the heavy curve ("conversion curve") in Fig. 17, for otherwise constant conditions, such as the composition of the gas mixture, rate of flow through the catalyst, etc.

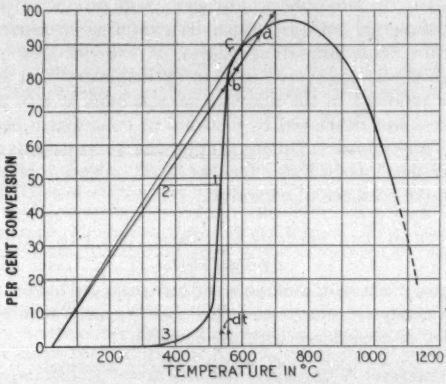
---

* Communicated by Professor Creighton.

† Concluded from page 610, Vol. 187, May, 1919.

The reaction is highly exothermic, the heat of reaction being practically constant and equal to 53,000 gram calories between 500° C. and 700° C. It has been calculated that, under the usual conditions of oxidation and on the assumption of 100 per cent. conversion, the heat of reaction is sufficient to raise the temperature of the moving gas mixture to 675° C. at the catalyst. If, therefore, the initial temperature of the ammonia-air mixture is 25° C., the temperature of the catalyst will be raised to 700° C. The smaller the percentage of ammonia converted into nitric oxide, the smaller will be the rise in temperature due to the heat

FIG. 17.



developed during the reaction, and the lower will be the temperature of the catalyst. The variation in the temperature of the catalyst with change in the percentage of ammonia converted is shown by the straight line ("heat-of-reaction line") in Fig. 17.

In a theoretical discussion of the conditions of stability of ammonia oxidation, Liljenroth,[6] in a recent paper, states: Since "the heat-of-reaction line cuts the conversion curve ordinarily at two points, *a* and *b* (Fig. 17), it seems, therefore, as if it would be possible to have two points of operation for any burner (heated catalyst) at a given gas composition and gas flow. But a closer investigation shows that the reaction cannot be main-

[6] Liljenroth, F. G., *Chem. Met. Eng.*, **19**, 287 (1918).

tained at the point *b* because the conditions for stability at this point are not fulfilled. Suppose that the burner is working at this point and that for some reason the temperature decreases by the small amount *dt*. Then the conversion will decrease to the point 1. This decrease will cause the temperature to be lowered still more, to point *2*, and this in turn will cause a new decrease in the conversion, to point *3*, and so on.

"If we assume that for some reason the temperature increases, it will in the same way be found that even in this case we move away from the point of intersection, which is indicated in the illustration by the arrows pointing apart from this point.

"If we treat the other point of intersection similarly (point *a*), it will be found that the conditions are just opposite. If for some reason we depart from the point, we will immediately be carried back to it, which is indicated by the two arrows, both pointing toward the point. Point *b* is therefore an unstable location, while point *a* is a stable one. As can easily be understood, this characteristic difference depends upon the manner in which the heat-of-reaction line cuts the conversion curve. In order to obtain stability, the heat-of-reaction line must cut the conversion curve from below, and from this it follows that the part of the conversion curve to the left of the tangenital point *c* is unstable, but that the part to the right is stable. It will also be understood that the stability or unstability increases with increase in the size of the angle at which the line and the curve cut each other.

"From what has been said regarding the unstability of the point *b*, we can now understand that the ammonia oxidation process is not self-starting or self-exciting, but that the gas, in order that the reaction may be started, must be heated by a flame or electricity" to the ignition temperature *T*, which lies considerably below the reaction temperature, after which the external heating may be interrupted and the reaction will move to the point *a*.

In practice the conversion curve and the heat-of-reaction line continually change their positions, on account of small variations in the composition and velocity of the gas mixture. A decrease in the ammonia content of the gas mixture causes the heat-of-reaction line to turn counter-clockwise about its point on the abscissa. "Ample margin between the points *a* and *c* must therefore be provided. If the top of the conversion curve is sharp, it will be impossible to work at a maximum efficiency, because we

have to move the working point farther to the right side, sacrificing efficiency in order to obtain stability. This also implies higher temperature. If the conversion curve is very flat, which seems to be the case in the ammonia oxidation reaction, it will be possible to work not only at the top point, but even a little to the left of it."

Of the various catalysts that have been employed for the oxidation of ammonia, the most satisfactory is platinum gauze of fine mesh, or smooth platinum the surface of which has been roughened by the deposition of a layer of platinum sponge. Platinum black or sponge alone is much too active. The best results are obtained with a thin layer of the catalyst, as a thick layer, or a low gas velocity, causes the nitric oxide that is formed to break down into its constituents. Other catalysts which have given good results are palladium, iridium, rhodium, iron, and the oxides manganese, lead, silver, copper, chromium, nickel, cobalt, vanadium and molybdenum, especially the higher oxides.

Particularly good results have been obtained in England with iron catalysts which have been activated with certain metals ("promoters") such as copper, bismuth, cerium, tungsten, etc. The percentage conversion obtained at 700° C. with a number of these activated iron catalysts is given in Table X, the time of contact of the gas mixture with the catalyst being 0.015 second.

TABLE X.

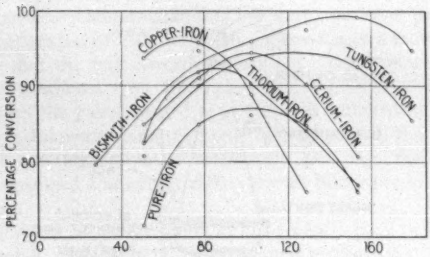
Catalyst.	Percentage conversion.
Pure iron	83.5
Iron-copper	86.0
Iron-thorium	87.3
Iron-tungsten	89.3
Iron-cerium	90.0
Iron-bismuth	92.0

The relative efficiency of these catalysts at different rates of flow of the gas mixture, and at 700° C., is shown graphically in Fig. 18.

Like all catalytic processes, the oxidation of ammonia suffers from the disadvantage that the catalyst is liable to be poisoned. It is necessary, therefore, to remove from the ammonia by suitable methods of purification all substances which poison the catalyst. While it has been believed that the presence of acetylene in the ammonia-air mixture had a marked deleterious effect on

the platinum in the oxidation of ammona, recent experiments have shown this to be due to the presence of phosphine and not to acetylene. The presence of 2 to 3 parts per hundred million of phosphine in the ammonia-air mixture lowers the yield of nitric oxide several per cent., while ten times this amount is ruinous. It is probable that the action of phosphine is cumulative, since the platinum appears to become less efficient with use.

FIG. 18.



Velocity of passage of gas mixture in liters per hour (at room temperature) per c.c. of free space in catalyst chamber. Each c.c. free space = 20 cm.² of catalyst surface.

THE TECHNICAL OXIDATION OF AMMONIA TO NITRIC OXIDE.

Although considerable progress has been made during the past few years in the technical oxidation of ammonia, but little detailed information is available regarding the various processes that have been developed. These processes conform to the following three types:

1. Oxidation by means of a platinum plug (Ostwald process);
2. Oxidation by means of an electrically heated platinum gauze;
3. Oxidation by means of base metal catalysts.

The principle of the first type of processes is that originally patented by Ostwald, but the catalyzer has been considerably modified, although it consists of metallic platinum. Little information regarding the details of the preparation of the catalyzer is available, but it is known to have a very small cross-section. It is placed at the end of a 60-mm. tube. The ammonia-air mixture is preheated before reaching the catalyzer, by utilizing the heat produced by the oxidation. No external heat is necessary. It is stated that the reaction when once started continues without

interruption for weeks. The yield is good, averaging 90 per cent., but the temperature regulation is more difficult than in the second type of processes, in which electrical heating is used.

The second type of processes possesses many advantages over processes of the Ostwald type, and is rapidly increasing in favor. A diagram [7] of a catalyzer used in a process (Frank and Caro's) of this second type is shown in Fig. 19. The catalyst is 80–100

FIG. 19.

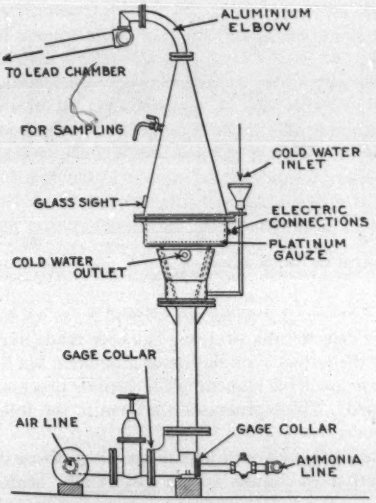


Diagram of Frank and Caro's catalyzer for ammonia oxidation.

mesh platinum gauze electrically heated to 700° C. At the bottom of the catalyzer the air enters on one side and the ammonia on the other. Before these gases mix, they pass through gauge collars, as indicated. The diameters of these collars are selected so that the best mixture for oxidation will be obtained. For further adjustment a valve is placed in each pipe-line. The gases are mixed by a revolving aluminium fan, after which they pass through the heated platinum gauze (no heat exchange taking

[7] *Chem. Met. Eng.*, **14**, 425, 1916.

place), where an almost quantitative conversion of the ammonia to nitric oxide occurs. The lower half of the casing surrounding the glowing platinum gauze is cooled by cold water, in order to prevent as far as possible any decomposition of the ammonia by radiated heat before it reaches the catalyst. The casing above the combustion chamber is lined with aluminium so as to prevent any iron oxide from falling on the catalyst.

The weight of platinum required for this catalyzer is about 47–50 grams per 100 kilograms of nitric acid per 24 hours. The loss due to wear and tear amounts to about 3 per cent. per month, and the gauzes have to be completely renewed once a month. It is probable that the unit described does not contain more than 50 grams of platinum.

To keep the gauze heated, 135 amperes supplied at 25 volts, *viz.*, 3.375 kilowatts, are required. If, therefore, the catalyzer produces 100 kilograms of nitric acid per day, the electrical energy consumed amounts to 0.81 kilowatt hours per kilogram of nitric acid.

A catalyzer in use in England has recently been described by Partington.[8] One form of this is shown in Fig. 20. This catalyzer consists of two aluminium cones, connected by three rectangular aluminium body pieces having a cross-section of 4 in. by 6 in. In the three lower junctions perforated baffle plates are inserted, while the junction between the top segment of the body and the upper cone is occupied by the catalyst frame. The ammonia-air mixture enters at the bottom and the nitrous gases leave at the top, through aluminium tubes having an internal diameter of 2 in. The upper cone is provided with a mica window for the inspection of the catalyst. This consists of one or more platinum gauzes which are stretched across the catalyzer at right angles to the gas flow. The gauzes, having 80 meshes to the inch, are made of pure platinum wire 0.0025 in. in diameter and weigh about 50 grams per square foot. The life of the gauze is about three months. New gauzes require to be used for a few hours before attaining their full catalytic activity.

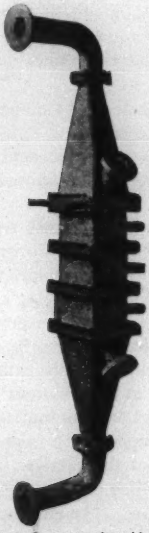
The ignition temperature is attained by heating the catalyst, either electrically or by means of a non-luminous gas flame, but once the reaction commences, the heat developed is sufficient to maintain the gauze at red heat, and conversion proceeds without interruption.

[8] Partington, J. R., *J. Soc. Chem. Ind.*, **37**, 337R (1918).

When working under established conditions with this catalyzer, a yield of one and one-half tons of nitric acid per square foot of catalyst area per 24 hours has been regularly attained, with a conversion efficiency of 95 per cent. Without the application of external heat, the efficiency is about 85 per cent.

The first ammonia oxidation plant established in the United States on a commercial scale was installed at the Ammo-Phos

FIG. 20.



Catalyzer for ammonia oxidation.

Works of the American Cyanamid Company, at Warners, New Jersey, in July, 1916. The catalyzer units at that time had a conversion capacity of 14 pounds of nitric acid per hour, but improvements in design and methods have since raised this figure to 40 pounds. The catalyst is heated electrically and consists of a single fine platinum gauze having an area of about two square feet. In this catalyzer the gas mixture passes downwards through the gauze. The high efficiency obtained with this catalyzer is

illustrated by a record for the week July 13 to 19, 1918, shown in Table XI.

At the United States Government Nitrate Plant at Muscle Shoals, nearly 700 catalyzers have been installed during the past year. Each of these consists of an aluminium box, having a cross-section of 14 in. x 28 in. and a height of 5 feet. At the base a sheet of platinum gauze weighing 143 grams is stretched at right angles to the gas flow. The gauze has 80 meshes to the inch and is made of wire 0.003 in. in diameter. Each catalyzer has an 8 kilowatt transformer, and is operated with 375 amperes at 21 volts.

At the Semet-Solvay Company's small plant, in Syracuse, N. Y., electrically heated, multiple platinum gauzes are employed.

TABLE XI.
Catalyzer No. 5.

Date.	Hour.	Conversion efficiency, Per cent.
July 13.....	2.35 A. M.	96.2
July 13.....	8.40 A. M.	98.5
July 13.....	5.20 P. M.	93.1
July 13.....	11.50 P. M.	96.0
July 14.....	5.50 A. M.	97.4
July 14.....	5.10 P. M.	94.8
July 15.....	10.35 A. M.	95.0
July 15.....	5.15 P. M.	95.8
July 16.....	1.50 A. M.	95.4
July 16.....	11.20 A. M.	95.4
July 17.....	1.10 A. M.	92.1
July 17.....	1.06 P. M.	92.3
July 18.....	12.50 A. M.	93.4
July 18.....	10.55 A. M.	92.6
July 18.....	8.00 P. M.	91.9
July 19.....	9.50 A. M.	93.6
Average for week.....		94.5

PRODUCTION, ENERGY REQUIREMENTS, COSTS.

Although ammonia oxidation plants are in operation in the United States, England, France, Germany, Italy and Russia, no information is available regarding the world's annual production of nitric acid from ammonia. It had been estimated that in the spring of this year in the United States the producing rate of nitric acid from ammonia, obtained by the fixation of atmospheric nitrogen, would be about 225,000 tons, 100 per cent. acid, per annum.

Owing to the signing of the armistice, however, it is probable that the government plant at Muscle Shoals will cease operation for a time. With the closing of this plant, there will be no nitric acid produced in this country by the oxidation of ammonia, with the exception of the small amount that is prepared from cyanamide ammonia at the Ammo-Phos Works of the American Cyanamid Company, at Warners, N. J., for operating their 50,000 ton sulphuric acid plant, and a small quantity produced at the works of the Semet-Solvay Company at Syracuse, N. Y.

The energy required for the production of nitric acid from ammonia is small. It consists of the electrical energy used in heating the catalyst, and the energy employed in operating the blowers which force the gas mixture through the catalyzer and that used in the absorption of the nitrous gases and in the concentration of the dilute nitric acid.

Owing to the high velocity of the ammonia-air mixture through the catalyzer, a comparatively large amount of ammonia can be oxidized with a relatively small catalyzer, and since the energy requirements are small, the conversion cost will be low. Estimates of this cost vary considerably, but it is probable, under normal conditions, that it is somewhat under one cent per pound of nitric acid, in the form of 53 per cent. acid. The total cost of nitric acid (93 per cent.) by the oxidation method is probably a little less than three cents per pound.

From a financial standpoint the production of nitric acid by the oxidation of ammonia can compete successfully with its production by the retort process from sodium nitrate, as the cost of conversion is about the same in both processes. Moreover, since sodium nitrate and ammonium sulphate have sold in the past at the same price per pound of nitrogen, ammonia is the cheaper form of nitrogen by the amount of sulphuric acid required to convert it into the sulphate. This, therefore, will make a difference of 15 to 20 per cent. in the cost of nitric acid, in favor of the oxidation of ammonia.

VII. COMPARATIVE DATA.

It may be of interest to compare the relative efficiencies of the arc process, the cyanamide process and the direct synthesis of ammonia, as these represent the three most important methods for the fixation of atmospheric nitrogen. By expressing coke, coal and other fuel in units of electrical energy, the quantity of nitro-

gen that may be fixed for a given energy consumption may be obtained. Thus, with one kilowatt year there can be fixed by the direct synthesis of ammonia, about 830 kilograms of nitrogen; by the cyanamide process, about 380 kilograms of nitrogen; and by the arc process, about 130 kilograms of nitrogen. The low energy consumption in the direct synthesis of ammonia is offset to some extent by the difficulties involved in operation, and the heavy dead charges; that in the cyanamide process by the large labor requirements and the number of operations involved. On the other hand, while the energy requirements of the arc process are high, it must be remembered that the labor involved is small, that its operation is extremely simple and that the raw materials are free.

In Table XII are given data [9] relating to investment and opera-

TABLE XII.

	Arc process.	Cyanamide process.	Direct synthesis of ammonia by	
			The Haber process.	The General Chemical Co. (De Jahn) process (*a*).
Product	35 per cent. HNO_3	NH_3	NH_3	NH_3
Investment	$1410 (*b*)	$440 (*b*)	$540	$300
Operating costs (*c*)	$170	$150 (*d*)	$119	$ 97
Product	96 per cent. HNO_3	96 per cent. HNO_3	96 per cent. HNO_3	96 per cent. HNO_3
Investment (*e*)	$1550	$670	$570	$530
Operating costs (*f*)	$220	$270	$239	$217

(*a*) Estimates on the Geneal Chemical Co. process are based on war time construction costs. All others on normal prices.
(*b*) Power plant investment reckoned at $100 per horse power.
(*c*) Amortization for cyanamide as charged by operating companies. Amortization for Haber 20 per cent. of plant cost for repairs, interest and depreciation. Amortization for Arc and Modified Haber 12.5 per cent. for interest and depreciation. $5.00 per ton of product for repairs.
(*d*) Cyanamide production $122, ammonia from cyanamide $28, total $150.
(*e*) Except for Arc process, includes ammonia plant as given; power additional, $10; oxidation and absorption, $140; concentration, $40; steam plant, $40.
(*f*) Except for Arc process, includes ammonia costs as given; oxidation, $50; concentration, $70. No allowance made for unoxidized ammonia.

tion costs, per ton of fixed nitrogen, for the arc, cyanamide and direct synthesis of ammonia processes.

During the past five years rapid progress has been made in the fixation of atmospheric nitrogen, especially by the cyanamide

[9] Nitrate Supply Committee Recommendations, *J. Ind. Eng. Chem.*, **9**, 841 (1917).

process and by the direct synthesis of ammonia. As a result of this advance, greatly stimulated by the war, nearly one-third of the nitrogen used by the Allies for military explosives in the autumn of 1918 was obtained from the atmosphere. That the nitrogen problem has been solved is attested by the following data showing the progress of the nitrogen industry:

ANNUAL PRODUCING CAPACITY IN TONS OF NITROGEN.

United States:	1914	1918 (Autumn)	1919 (Spring) (estimate)
Cyanamide	0	46,000	91,000
Synthetic ammonia	0	9,000	9,000
Total atmospheric nitrogen	0	55,000	100,000
By-product ammonia	38,000	90,000	100,000
Grand total	38,000	145,000	200,000
The World:			
Cyanamide	53,000	265,000	343,000
Synthetic ammonia	12,000	109,000	109,000
Arc process nitrogen	10,000	15,000	15,000
Total atmospheric nitrogen	75,000	389,000	467,000
By-product ammonia	300,000	350,000	360,000
Sodium nitrate	430,000	500,000	520,000
Grand total	805,000	1,239,000	1,347,000

BIBLIOGRAPHY OF LITERATURE ON AND RELATING TO NITROGEN FIXATION, AND THE OXIDATION OF AMMONIA.

GENERAL.

1877.

BERTHELOT, M.: "Absorption of Free Nitrogen by the Proximate Principles of Vegetables Under the Action of Atmospheric Electricity." *Compt. rend.*, **83**, 677.

BERTHELOT, M.: "Fixation of Nitrogen on Organic Substances Under the Influence of Feeble Electric Tensions." *Compt. rend.*, **85**, 173.

1903.

FRANK, A.: "Rendering Atmospheric Nitrogen Available for Agriculture and Industry." *Zeitschr. angew. Chem.*, **16**, 536.

1904.

WIESLER, A.: "The Utilization of Free Nitrogen." *Zeitschr. angew. Chem.*, **17**, 1713.

1905.

BOILEAU, A.: "Utilization of Atmospheric Nitrogen." *Génie Civil*," **47**, 293.

NEUBURGER, A.: "The Utilization of Atmospheric Nitrogen." *Zeitschr. angew. Chem.*, **18**, 1761, 1810, 1843.
WITT, O. N.: "On the Utilization of Atmospheric Nitrogen." *Chem. Ztg.*, **29**, 1261; *Chemische Ind.*, **28**, 699.

1906.

ANON: "Fixation of Atmospheric Nitrogen." *Engineering*, **81**, 89.
GUYE, P. A.: "The Electrochemical Problem of the Fixation of Nitrogen." *J. Soc. Chem. Ind.*, **25**, 567.
LEMAIRE, E.: "The Utilization of Atmospheric Nitrogen." *Génie Civil*, 48, 308, 328.

1907.

FRANKLAND, P. F.: "The Utilization of Atmospheric Nitrogen for Industrial Purposes." *J. Soc. Chem. Ind.*, **26**, 175.
GUYE, P. A.: "Electrochemical Problems of the Fixation of Nitrogen." *Mon. sci.*, **21**, 225.

1911.

ANON: "Fixation of Atmospheric Nitrogen." *Revue Gen. des Sciences*, 908.
BECKMANN, J. W.: "The Fixation of Atmospheric Nitrogen." *Elec. Rev. West. Elec.*, **59**, 533.
HASENCLEVER, M.: "The Fixation of Atmospheric Nitrogen." *J. Soc. Chem. Ind.*, **30**, 1294.
KERSHAW, J. C. B.: "Recent Progress in the Fixation of Atmospheric Nitrogen." *Elec. World*, **57**, 1035.
LAMY, E.: "The Industrial Fixation of Atmospheric Nitrogen." *Met. Chem. Eng.*, **9**, 99.
MAROWETZKY, A.: "Formation of Nitric Acid and Ammonia by the Electric Discharge With Water as One Electrode." *Zeitschr. Elektrochem.*, **17**, 217.
SCOTT, E. K.: "Manufacture of Nitrogen Compounds by Electric Power." *Electrician*, **67**, 886.
STRUTT, R. J.: "A Chemical Active Modification of Nitrogen Produced by the Silent Discharge." *Proc. Roy. Soc.*, A, **85**, 219.

1912.

AUZIES, J. A. A.: "Technical Conversion of Nitrogen Into Its Compounds." *Rev. gen. Chim. pur. appl.*, **15**, 233; *J. Soc. Chem. Ind.*, **31**, 919.

1913.

ANON: "Progress in Nitrogen Fixation in Scandinavia." *Times Eng. Suppl.*, Oct. 15.
COMPTE, F.: "A Chemical Active Modification of Nitrogen." *Physik. Zeitschr.*, **14**, 74.
TIEDE, E., and DOMEKE, E.: "The Question of Active Nitrogen." *Ber.*, **46**, 4095.

1915.

ADAMS, M.: "Electro-Manufacture of Nitrates." *J. Elec. Power. Gas*, **34**, 190.
BRINER, E.: "The Rôle of Ionization in the Fixation of Nitrogen." *J. Chim. Phys.*, **13**, 18.

KOENIG, A.: "Electrical Activation of Nitrogen." *Zeitschr. Elektrochem.*, **21**, 267.

PRINSEN-GEERLIGS, H. C.: "Fixation of Atmospheric Nitrogen." *Louisiana Planter*, **54**, 347.

SANDER, A.: "Significance of the Nitrogen Industry in the Present War." *Zeitschr. komp. flüss. Gase*, **17**, 1.

STRUTT, R. J.: "Chemically Active Modification of Nitrogen Produced in the Electric Discharge." *Proc. Roy. Soc.*, A, **91**, 303.

SUMMERS, L. L.: "Fixation of Atmospheric Nitrogen." *Trans. Amer. Electrochem. Soc.*, **27**, 339.

UHLMANN, P. W.: "Nitrogen Problems After the War." *Chem. Ztg.*, **39**, 713.

WEINWURM, E.: "The New Nitrogen Industry." *Elektrotechn. u. Machinenbau*, **33**, 3.

1916.

ANON.: "Our Nitrogen Demand and Supply in Advent of War." *J. Ind. Eng. Chem.*, **8**, 1088.

GILBERT, C. G.: "Sources of Nitrogen Compounds in the United States." *Smithsonian Pub.*, No. 2421.

HOSMER, H. R.: "Literature of the Nitrogen Industries," 1912–1916. *Gen. Elec. Rev.*, **20**, 76.

LANDIS, W. S.: "Niagara Falls Power and American Industry." IV. Nitrogen Fixation. *Trans. Amer. Electrochem. Soc.*, **29**, 79.

SCARPA, O.: "Electrochemical Industry of Atmospheric Nitrogen." *Ann. chim. applicata*, **7**, 27.

SKERRETT, R. G.: "Fixation of Atmospheric Nitrogen." *Iron Age*, **97**, 359.

STRONG, W. W.: "Electrometallurgical Uses of Surplus Power." *J. Elec. Power and Gas*, **37**, 43.

SCOTT, E. K.: "Direct and Indirect Methods for Making Nitric Acid." *Electrician*, **78**, 215.

1917.

ANON.: "The Nitrogen Problem and the Work of the British Nitrogen Products Committee." *Chem. News*, **166**, 240.

ANON: "Nitrate Supply Committee Recommendations on Synthetic Nitric Acid for the Government, with Reports on Various Methods." *J. Ind. Eng. Chem.*, **9**, 829.

ANON.: "A Review of the Italian Atmospheric Nitrogen Fixation Industry." *Elettrotecnica*, **4**, 102.

FLORENTIN, D.: "Fixation of Atmospheric Nitrogen." *Génie Civil*, **70**, 333, 353, 369, 384.

HOSMER, H. R.: "Literature of the Nitrogen Industries," ii, iii, iv, 1912–1916. *Gen. Elec. Rev.*, **20**, 156, 252; *J. Ind. Eng. Chem.*, **9**, 424.

LONG, F. M.: "War-time Developments in England." *Elec. Rev. West. Elec.*, **71**, 65.

NAUCHKOFF, S.: "How Do the Warring Nations Obtain Their Nitrogen Supply?" *Met. Chem. Eng.*, **17**, 525.

SCOTT, E. K.: "Extracting Nitrogen From the Air by Electric Power." *Elec. Eng.* **50**, 45.

1918.

ANON.: "Electricity for Government Nitrate Plants." *Elec. World*, **71**, 1358.

AUSTIN, O. P.: "The Beginning of the Atmospheric Nitrogen Industry in America." *The Americas*, **4**, 21.

BROWN, F. W.: "The Source of Our Nitrogen Fertilizers." *Amer. Fertilizer*, **48**, 57.

LANDIS, W. S.: "The War and the Nitrogen Industry." *Chem. Met. Eng.*, **19**, 828.

MORSELLI, G.: "Synthetic Nitrogen Products." *Chem. Trade J.*, **63**, 182.

NOYES, A. A.: "The Nitrogen Problem in Relation to the War." *J. Wash. Acad. Sci.*, **8**, 381.

SCOTT, E. K.: "Electrical Power for Nitrogen Fixation." *Proc. Amer. Inst. Elec. Eng.*, 779.

STEINMETZ, C. P., *et al.*: "Electrical Power for Nitrogen Fixation." *Proc. Amer. Inst. Elec. Eng.* (advance copy).

1919.

ANON.: "The Fixation of Atmospheric Nitrogen in Germany During the War." *J. four élec.*, **28**, 15.

CROWELL, B.: "Cost of the Muscle Shoals Nitrate Plant." *Elec. World*, **73**, 281.

FAIRLIE, A. M.: "Muscle Shoals Nitrate Plant." *Chem. Met. Eng.*, **20**, 8.

WHITE, A. H.: "The Present Status of Nitrogen Fixation." *J. Ind. Eng. Chem.*, **11**, 231.

DIRECT OXIDATION.

1786–1880.

BERTHELOT, M.: "Heat Evolved in Various Reactions of the Oxides of Nitrogen." *Compt. rend*, **78**, 162, 205 (1874).

BERTHELOT, M.: "Researches on the Oxygen Compounds of Nitrogen." *Ann. chim. phys.* (v) **6**, 190, (1875).

BERTHELOT, M.: "Does Ozone Combine with Free Nitrogen in the Presence of Alkalis to Form Nitrites and Nitrates?" *Compt. rend.*, **84**, 61 (1877).

CAVANDISH, H.: "Experiments on Air." *Phil. Trans. Roy. Soc.*, **75**, 372 (1786).

HOWZEAU, A.: "Experiment on the Electrification of Air or Oxygen as a Means for the Production of Ozone." *Ann. chim. phys.*, (iv) **22**, 150 (1871).

PERROTT, A.: "Research on the Chemical Action of the Induction Spark of the Ruhmkorff Apparatus." *Ann. chim. phys.*, (iii) **61**, 161 (1861).

1881.

HAUTEFEUILLE, P., and CHAPPIUS, J.: "Spectra of Compound Gases and a New Compound of Nitrogen and Oxygen." *Compt. rend.*, **92**, 80.

1885.

RAMSAY, W., and CUNDALL, J. T.: "The Oxides of Nitrogen." *J. Chem. Soc.*, **47**, 187, 672.

1887.

RICHARDSON, A.: "Action of Heat on Peroxide of Nitrogen." *J. Chem. Soc.*, **51**, 397.

1889.

HOSVAY, DE H.: "Formation of Ozone and Nitrogen Acids in Combustion." *Bull. Soc. Chim.*, (iii) **2**, 734.

VEITH, A.: "On the Combination of Nitrogen and Oxygen in Explosions." *Ber.*, **22** (R), 169.

1890.

HEMPEL, W.: "Combustions Under High Pressure." *Ber.*, **23**, 1455.

RAMSAY, W.: "Nitrogen Trioxide and Nitrogen Peroxide." *J. Chem. Soc.*, **57**, 590.

1892.

CROOKES, W.: "The Flame of Burning Nitrogen." *Chem. News*, **65**, 301.

1897.

LEPEL, F. VON: "The Oxidation of Nitrogen by Electric Sparks and Arcs." *Ber.*, **30**, 1027.

RAYLEIGH, LORD: "Observations on the Oxidation of Nitrogen Gas." *J. Chem. Soc.*, **71**, 181.

1899.

DIXON, H. B., and PETERKIN, J. D.: "The Action of Nitric Oxide on Nitrogen Peroxide." *J. Chem. Soc.*, **75**, 613.

1900.

MACDOUGALL, A., and HOWLES, F.: "On the Production of Nitric Acid From Air by Means of the Electric Flame." *Manchester Lit. and Phil. Soc. Mem.*, **44**, 1.

SALVADORI, R.: "Oxidation of Nitrogen." *Gazzetta*, (ii) **30**, 389.

1902.

ANON.: "Nitric Acid From Atmospheric Nitrogen at Niagara Falls." *Electrician*, **49**, 684.

1903.

HABER, F.: "Electro-Chemical Engineering in the United States." *Zeitschr. Elektrochem.*, **9**, 381.

KOWALSKI, J. DE: "The Production of Nitric Acid by Electric Discharges." *Bull. Soc. Intern. Elec.*, (ii) **3**, 314.

LEPEL, F. V.: "Oxidation of Atmospheric Nitrogen by Electric Discharges." *Ber.*, **36**, 1251.

MUTHMANN, W., and HOFER, H.: "Burning of Nitrogen to Nitric Oxide in the Electric Flame." *Ber.*, **36**, 438.

VOLVEY, C. W.: "On the Formation of Nitric Acid by Electrical Energy." *Trans. Amer. Electrochem. Soc.*, **3**, 285.

VOLVEY, C. W.: "Manufacture of Nitric Acid." *J. Soc. Chem. Ind.*, **22**, 780.

1904.

EDSTRÖM, J. S.: "Electrical Extraction of Nitrogen From the Air." *Electrochem. Ind.*, **2**, 399.

FICHTER, F.: "The Formation of Nitric Acid From Its Elements Under the Influence of Electric Discharges." *Zeitschr. angew. Chem.*, **17**, 1181.

1905.

BOILEAU, A.: "Electric Manufacture of Cyanides and Nitrates." *Génie Civil*, **47**, 293.

BRODE, J.: "Oxidation of Nitrogen in the High-Tension Flame." *Zeitschr. Electrochem.*, **11**, 752.

FINCKH, K.: "Determination of Chemical Equilibrium." *Zeitschr. anorg. Chem.*, **45**, 116.

LAVETH, H. R., and RAND, C. L.: "Production of Nitric Acid From Air." *Zeitschr. angew. Chem.*, **18**, 1906.

NERNST, W.: "Determination of Chemical Equilibrium." *Zeitschr. anorg. Chem.*, **45**, 126.

ROSSI, E.: "A New Method of Preparing Oxides of Nitrogen and Nitric Acid From Compressed Air by Electrical Means." *Gazzetta*, **35**, 89.

SCHEUER, O.: "Preparation of Oxides of Nitrogen by High-Tension Discharge." *Zeitschr. Elektrochem.*, **11**, 565.

STAVENHAGEN, A.: "The Oxidation of Atmospheric Nitrogen in the High-Tension Arc Flame." *Ber.*, **38**, 2171.

WINTELER, F.: "Production of Nitric Acid From Atmospheric Nitrogen." *Chem. Ztg.*, **29**, 1278.

1906.

BERTHELOT, M.: "Direct Synthesis of Nitric Acid and Nitrates From the Elements at Ordinary Temperature." *Compt. rend.*, **142**, 1367.

BIRKELAND, K.: "The Oxidation of Atmospheric Nitrogen in the Electric Arc." *Trans. Faraday Soc.*, 2, 98.

BODENSTEIN, M.: "The Production of Nitric Acid From Air." *Zeitschr. angew. Chem.*, **19**, 14.

FISCHER, F., and BRAEHMER, F.: "The Conversion of Oxygen Into Ozone at High Temperatures and the Oxidation of Nitrogen." *Ber.*, **39**, 940.

FISCHER, F., and MARX, H.: "Thermal Relationships in the Formation of Ozone and Nitric Oxide." *Ber.*, **39**, 2257, 3631.

FOERSTER, F.: "On the Technical Experiments on the Combustion of Nitrogen." *Zeitschr. Elektrochem.*, **12**, 529.

JELLINEK, K.: "Velocity of Decomposition of Nitric Oxide and Its Dependence on Temperature." *Zeitschr. anorg. Chem.*, **49**, 229.

KAUSCH, O.: "The Manufacture of Oxygen-Nitrogen Compounds From Air by Electricity." *Elektrochem. Zeitschr.*, **13**, 93.

LEBLANC, M.: "Reactions of Nitric Oxide." *Zeitschr. Elektrochem.*, **12**, 541.

NERNST, W.: "Formation of Nitric Oxide at High Temperatures." *Zeitschr. anorg. Chem.*, **49**, 213.

SMITH, N.: "Oxidation of Nitrogen." *J. Chem. Soc.*, **89**, 475.

WARBURG, E., and LEITHÄUSER, G.: "Oxidation of Nitrogen by Silent Discharge in Atmospheric Air." *Ann. Physik*, (iv) **20**, 743.

1907.

ANON.: "Saltpetre From Air." *Zeitschr. Elektrochem.*, **13**, 75.

BRION, DR.: "Investigation of the High-Tension Arc." *Ibid.*, **13**, 761.

FISCHER, F., and MARX, H.: "Thermal Relationships in the Formation of Ozone and Nitric Oxide." *Ber.*, **40**, 443, 1111.

GRAU, A., and RUSS, F.: "Validity of the Law of Mass Action for the Combustion of Nitrogen in the High-Tension Flame." *Zeitschr. Elektrochem.*, **13**, 545, 573.

HABER, F., and KOENIG, A.: "Nitric Oxide Formation in the High-Tension Arc." *Ibid.*, **13**, 725.

LEBLANC, M., and NÜRANEN, W.: "The Validity of the Law of Mass Action in the Combustion of Nitrogen in the High-Tension Flame." *Ibid.*, **13**, 297.

LEE, H., and BEYER, A.: "Electric Heating of Air." *Ibid.*, **13**, 701.

RUSS, F.: "On the Combustion of Air." *Oesterr. Chem. Ztg.*, **10**, 237.

1908.

FOERSTER, F., and KOCH, M.: "Interaction of Nitrous Gases and Oxygen with Water." *Zeitschr. angew. Chem.*, **21**, 2161, 2209.

GRAU, A., and RUSS, F.: "Combustion of Air in the Electric Arc." *Sitz. Ber. Weiner Akad. d. Wiss.*, **117**, 321.

HABER, F., and KOENIG, A.: "Nitric Oxide Formation in High-Tension Arcs." *Zeitschr. Electrochem.*, **14**, 689.

HOLWEG, W.: "Reactions Between Nitric Oxide and Oxygen." *Zeitschr. angew. Chem.*, **21**, 2131.

LÖB, W.: "Action of the Silent Electric Discharge Upon Moist Nitrogen and Moist Nitric Oxide." *Zeitschr. Elektrochem.*, **14**, 556.

MANDL, A., and RUSS, F.: "Union of Nitric Oxide and Oxygen." *Zeitschr. angew. Chem.*, **21**, 486.

MORDEN, G. W.: "Formation of Nitric Oxide From Air by Means of an Electric Current of Low Voltage." *Trans. Amer. Electrochem. Soc.*, **14**, 113.

SCHÖNHERR, DR.: "The Oxidation of Atmospheric Nitrogen." *Zeitschr. angew. Chem.*, **21**, 1633.

1909.

ANON: "Hydro-Electric Installations at Notodden, Norway." *Engineering*, **88**, 611.

ANON.: "Manufacture of Nitrates From the Air in Germany." *Board of Trade J.*, Aug. 19th.

BERNTHSEN, A.: "Utilization of Atmospheric Nitrogen for the Production of Air-Saltpetre." *J. Ind. Eng. Chem.*, **1**, 466.

BRINER, E., and DURAND, E. L.: "Chemical Action in the Electric Discharge at Low Temperatures." *J. chim. phys.*, **7**, 1.

EYDE, S.: "Manufacture of Nitrates From the Atmosphere by the Electric Arc." *J. Roy. Soc. Arts*, **57**, 568; *Electrician*, **63**, 334.

GUYE, P. A.: "The Industrial Fixation of Nitrogen." *Bull. Soc. Chim.*, (iv) **5**, 1.

RUSS, F.: "Manufacture of Nitric Acid From the Air in Austria." *Zeitschr. Elektrochem.*, **15**, 544.

SCHÖNHERR, DR.: "Manufacture of Nitric Acid From Air." *Elektrotechn. Zeitschr.*, **30**, 366, 397; *Trans. Amer. Electrochem. Soc.*, **16**, 131.

1910.

ANON.: "Process for Preparing Nitric Acid of 65 Per Cent. by Absorption in Water of Oxides of Nitrogen Mixed with Oxygen." *J. Soc. Chem. Ind.*, **29**, 211.

FOERSTER, F., and BLICK, J.: "Behavior of Nitrous Gases Towards Water and Aqueous Alkali Solutions." *Zeitschr. angew. Chem.*, **23**, 2017.

HABER, F.: "Formation of Nitric Acid From the Air." *Chem. Ztg.*, **34**, 283.

HABER, F., and HOLWECH, W.: "Formation of Nitric Oxide From the Air in the Arc Flame Under Pressure." *Zeitschr. Elektrochem.*, **16**, 810.

HABER, F., and KOENIG, A.: "Oxidation of Atmospheric Nitrogen." *Ibid.*, **16**, 11.

HABER, F., KOENIG, A., and PLATOU, E.: "Formation of Nitric Acid in High-Tension Arcs." *Ibid.*, **16**, 789.

HABER, F., and PLATOU, E.: "Nitric Oxide Formation From Air by Means of High Frequency Alternating Current Discharges." *Ibid.*, **16**, 796.

HOLWECH, W.: "The Relation of Nitric Oxide Formation to the Electrical and Thermal Properties of Short Continuous Current Arcs With Cooled Electrodes." *Ibid.*, **16**, 369.

HOLWECH, W., and KOENIG, A.: "Yield of Nitric Acid From Air With Cooled Continuous Current Arcs." *Ibid.*, **16**, 83.

ZENNECK, J.: "Utilization of Atmospheric Nitrogen by Means of the Flaming Arc." *Physik. Zeitschr.*, **11**, 1228.

1911.

EHRLICH, V., and RUSS, F.: "The Oxidation of Nitrogen by the Silent Discharge in the Presence of Ozone." *J. Soc. Chem. Ind.*, **30**, 1393.

LAMY, E.: "The Industrial Fixation of Atmospheric Nitrogen." *Met. Chem. Eng.*, **9**, 100.

LEWIS, G. N., and EDGAR, A.: "The Equilibrium Between Nitric and Nitrous Acids and Nitric Oxide." *J. Amer. Chem. Soc.*, **33**, 292.

STRUTT, R. J.: "The Flame Arising From the Nitrogen-Burning Arc." *Proc. Roy. Soc.*, A **85**, 533.

VANDERPOEL, J.: "A French Plant for the Fixation of Atmospheric Nitrogen" (Pauling Process). *Met. Chem. Eng.*, **9**, 196.

1912.

ANON.: "Fixation of Nitrogen." *Chem. Trade J.*, **50**, 622.

BRINER, E., and DURAND, E. L.: "Conditions of Formation of Nitrous and Nitric Acids From the Oxides of Nitrogen and Water." *Compt. rend.*, **155**, 582.

EYDE, S.: "Oxidation of Atmospheric Nitrogen and the Development of the Resulting Industry in Norway." *Met. Chem. Eng.*, **10**, 617; *J. Ind. Eng. Chem.*, **4**, 771.

FISCHER, F., and HENE, E.: "Chemistry of Nitric Oxide Formation in the High-Temperature Arc." *Ber.*, **45**, 3652.

HAUSSER, F.: "Oxidation of Nitrogen in Explosive Gas Mixtures." *Zeitschr. Ver. deutsch. Ing.*, **56**, 1157.

LOWRY, T. M.: "Oxidation of Atmospheric Nitrogen in the Presence of Ozone." *J. Chem. Soc.*, **101**, 1152.

RUSS, F.: "Oxidation of Nitrogen and Active Nitrogen." *Zeitschr. angew. Chem.*, **25**, 586.

SCOTT, E. K.: "Manufacture of Nitrates From the Atmosphere." *J. Roy. Soc. Arts*, **60**, 645.

TAUSENT, M.: "Comparative Experiments on the Oxidation of Nitrogen in the High-Pressure Electric Flame." *Zeitschr. Elektrochem.*, **18**, 314.

1913.

BRINER, E., and BOUBNOFF, N.: "Investigation Into the Decomposition of Nitric Oxide." *Compt. rend.*, **156**, 228.

BRINER, E., and BOUBNOFF, N.: "Decomposition of Nitric Oxide at High Pressures." *J. chim. phys.*, **11**, 597.

COMPTE, F.: "Chemically Active Modification of Nitrogen." *Physik. Zeitschr.*, **14**, 74.

FISCHER, F., and HENE, E.: "Chemistry of Nitric Oxide Formation in the High-Temperature Arc." *Ber.*, **46**, 603.

GORBOV, A. I., and MITKEVICH: "Combustion of Air in the Voltaic Arc." *J. Russ. Phys. Chem. Soc.*, **45**, 1109.

KOENIG, A.: "Chemistry of Nitric Oxide Formation in High-Tension Arcs." *Ber.*, **46**, 132.

KOENIG, A., and ELÖD, E.: "Oxidation of Nitrogen by the Electric Discharge." *Ibid.*, **46**, 2998.

PERKINS, F. C.: "Schönherr and Birkeland-Eyde Electric Nitrate Furnaces." *Chem. Eng.*, **18**, 238.

SAPOZHNIKOV, A., *et al.*: "Influence of Some Conditions on the Successful Oxidation of Nitrogen in the Voltaic Arc." *J. Russ. Phys. Chem. Soc.*, **45**, 1076.

TIEDE, E.: "Activation of Nitrogen." *Ber.*, **46**, 340.

1914.

ANON.: "New Processes and Apparatus for the Electric Fixation of Nitrogen." *Elektrochem. Zeitschr.*, **21**, 211.

ARGO, W. L.: "Rate of Dissociation of Nitrogen Peroxide." *J. Phys. Chem.*, **18**, 438.

HENE, E.: "Formation of Nitrogen Oxides in the High-Tension Arc." *Elektrochem. Zeitschr.*, **35**, 745.

KOENIG, A., and ELÖD, E.: "Oxidation of Nitrogen by the Electric Discharge." II. "Activation of Nitrogen and Oxygen." *Ber.*, **47**, 516.

LOWRY, T. M.: "An Oxidizable Variety of Nitrogen." *Phil. Mag.*, **28**, 412.

NAGIHIN, S.: "Synthesis of Nitric Acid in the Flame of the Laboratory Burner." *Chem. Ztg.*, **37**, 469.

ROSELIER, E.: "Synthesis of Nitrogen Oxides in the Electric Arc." *Rev. Electrochem. Electrometal.*, **8**, 33, 97.

1915.

KEUTEL, F.: "Preparation of Nitric Acid from Air by the Electric Arc." (Lecture experiment.) *Zeitschr. physik. chem. Unterr.*, **28**, 261.

SCOTT, E. K.: "Production of Nitrates From Air." *Chem. Trade J.*, **56**, 43.

SCOTT, E. K.: "Production of Nitric Acid From Air, With Special Reference to a New Electric Furnace." *J. Soc. Chem. Ind.*, **34**, 113, 258.

1916.

SCARPA, O.: "Manufacture of Nitric Acid From Atmospheric Nitrogen." *Elettrotecnica*, **3**, 618.

SCOTT, E. K.: "Direct and Indirect Methods for Making Nitric Acid." *Electrician*, **78**, 215.

1917.

ANON.: "Nitrate Supply Committee Recommendations on Synthetic Nitric Acid for the Government, With Reports on Various Methods." *J. Ind. Eng. Chem.*, **9**, 834.

1918.

ANON.: "The Manufacture of Ammonium Nitrate by the Kilburn-Scott Process." *L'Industrie chim.*, **5**, 80.

BODENSTEIN, M.: "Velocity of the Reaction Between Nitric Oxide and Oxygen." *Zeitschr. Elektrochem.*, **24**, 183.

BRINER, E., and FRIDÖRI, F.: "The Rate of Oxidation of Nitric Oxide." *J. chim. phys.*, **16**, 279.

GRIEPE, A. W. H.: "Nitric Acid as a By-Product of Internal-Combustion Engines." *Amer. Gas Eng. J.*, **109**, 487, 492.

SCOTT, E. K.: "Nitrogen-Fixation Furnaces." *Gen. Elec. Rev.*, **21**, 793; *Chem. Met. Eng.*, **19**, 441.

TAYLOR, G. B., CAPPS, J. H., and COOLIDGE, A. S.: "The Production of Nitric Acid From Nitrogen Oxides." *J. Ind. Eng. Chem.*, **10**, 270.

1919.

PARTINGTON, J. R., and PARKER, L. H.: "The Theory of Absorption Towers in Nitric Acid Manufacture." *J. Soc. Chem. Ind.*, **38**, 75T.

DIRECT COMBINATION WITH HYDROGEN.

1884.

RAMSAY, W., and YOUNG, S.: "Decomposition of Ammonia by Heat." *J. Chem. Soc.*, **45**, 88.

1902.

HEMPTINNE, A. DE: "Synthesis of Ammonia From Its Elements." *Bull. Acad. roy. Belg.*, 1902, 28.

1905.

HABER, F., and VAN OORDT, G.: "On the Formation of Ammonia From Its Elements." *Zeitschr. anorg. Chem.*, **43**, 111; **44**, 341.

PERMAN, E. P.: "The Direct Synthesis of Ammonia." *Chem. News*, **91**, 283.

1907.

BRINER, E., and METTLER, E.: "Formation of Ammonia From Its Elements by the Action of the Electric Spark; Influence of Pressure." *Compt. rend.*, **144**, 694.

BRUNEL, L., and WOOG, P.: "Synthesis of Ammonia by Catalysis." *Compt. rend.*, **145**, 922.

HABER, F., and LEROSSIGNOL, R.: "On the Ammonia Equilibrium." *Ber.*, **40**, 2144.

NERNST, W., and JOST, F.: "On the Ammonia Equilibrium." *Zeitschr. Elektrochem.*, **13**, 521.

1908.

BRINER, E., and METTLER, E.: "Formation of Ammonia From Its Elements by the Action of Electric Discharges." *J. chim. phys.*, **6**, 137.

DAVIES, J. H.: "Formation and Decomposition of Ammonia by Silent Electric Discharge in a Siemens tube, With Special Regard to the Applicability of the Law of Mass Action." *Zeitschr. physik. Chem.*, **64**, 657.

JOST, F.: "On the Ammonia Equilibrium." *Zeitschr. Elektrochem.*, **14**, 373.

WOLTERECK, H. C.: "Synthesis of Ammonia." *Compt. rend.*, **146**, 124.

1909.

LIPSKI, J.: "Synthesis of Ammonia From Its Elements." *Zeitschr. Elektrochem.*, **15**, 189.

1910.

HABER, F.: "Preparation of Ammonia From Hydrogen and Nitrogen." *Zeitschr. Elektrochem.*, **16**, 244.

NERNST, W.: "Specific Heat and Chemical Equilibrium of Ammonia Gas." *Ibid.*, **16**, 96.

1911.

CARDELL, I. S., and THOMAS, F.: "Synthesis of Ammonia by Heat." *Proc. Chem. Soc.*, **27**, 138.

JELLINEK, K.: "Rôle of Iron as Catalyst in Ammonia Synthesis Under Pressure." *Zeitschr. anorg. Chem.*, **71**, 121.

1912.

BERNTHESEN, A. "Synthetic Ammonia Realized. The Haber Process in the Hands of the Badische Company." *Met. Chem. Eng.*, **10**, 637; *J. Ind. Eng. Chem.*, **4**, 760.

BILLITER, J.: "Synthesis of Ammonia From Its Elements." *Nernst Festschrift*, 1912, 86; *J. Soc. Ind. Chem.*, **31**, 919.

1913.

HABER, F., and LE ROSSIGNOL, R.: "The Technical Preparation of Ammonia From Its Elements." *Zeitschr. Elektrochem.*, **19**, 53.

1914.

ANON.: "A Plant for the Synthetic Manufacture of Ammonia." *Chem. Ztg.*, **37**, April 23d.

CROSSLEY, A. W.: "Preparation and Commercial Uses of Hydrogen and Synthetic Ammonia." *Chem. Trade J.*, **54**, 497.

HABER, F.: "On the Synthetic Production of Ammonia." *Oesterr. Chem. Ztg.*, **17**, 165.

NAGIBIN, S.: "Synthesis of Ammonia in the Flame of the Laboratory Burner." *Chem. Ztg.*, **37**, 469.

SERPEK, O.: "Inorganic Synthesis of Ammonia." *Zeitschr. angew. Chem.*, **27**, *Aufsatz*, 41.

1915.

DE JAHN, F. W.: "Synthetic Production of Ammonia." *Chem. Abstr.*, **9**, 1978, 2295, 2799.

HABER, F.: "Heat of Formation and Specific Heat of Ammonia." *Chem. Ztg.*, **39**, 24.

HABER, F., and GREENWOOD, H. C.: "Action of Uranium as Catalyst in the Synthesis of Ammonia From Its Elements." *Zeitschr. Elektrochem.*, **21**, 241.

HABER, F., and MASCHKS, A.: "Ammonia Equilibrium at Ordinary Pressure." *Ibid.*, **21**, 128.

HABER, F., and TAMARU, S.: "Determination of the Heat of Formation of Ammonia at High Temperatures." *Ibid.*, **21**, 191.

HABER, F., and TAMARU, S.: "The Specific Heat of Ammonia." *Ibid.*, **21**, 228.

HABER, F., TAMARU, S., and OEHOLM, L. W.: "Determination of the Heat of Formation of Ammonia at Ordinary Temperatures." *Ibid.*, **21**, 206.

HABER, F., TAMARU, S., and PONNAZ, C.: "Determination of the Ammonia Equilibrium at a Pressure of 30 Atmospheres." *Ibid.*, **21**, 89.

1916.

ZENGHELIS, C.: "Synthesis of Ammonia." *Compt. rend.*, **162**, 914.

1917.

ANON.: "Nitrate Supply Committee Recommendations on Synthetic Nitric Acid for the Government, With Reports on Various Methods." *J. Ind. Eng. Chem.*, **9**, 835.

DAVIS, R. O. E., and BRYAN, H.: "Synthesis of Ammonia by the Haber Process." *Amer. Fertilizer*, **47**, 29.

MAXTED, E. B.: "Synthesis of Ammonia and Its Oxidation to Nitric Acid." *J. Soc. Chem. Ind.*, **36**, 777.

1918.

BAUNARD, W.: "How to Make Synthetic Ammonia." *Sugar*, **20**, 217.

HAMBURGER, L.: "Electrochemical Gas Reactions Involving Nitrogen." *Chem. Weekblad*, **15**, 931.

LUDLAM, E. B.: "Effect of Hydrogen Chloride on the Ammonia Equilibrium." *Chem. Trade J.*, **61**, 505.

MAXTED, E. B.: "Synthesis of Ammonia at High Temperatures." *J. Chem. Soc.*, **113**, 168, 386.

MAXTED, E. B.: "Notes on the Catalytic and Thermal Synthesis of Ammonia." *J. Soc. Chem. Ind.*, **37**, 105T, 232T.

COMBINATION WITH CARBIDES.—CYANAMIDE.

1903.

FRANK, A.: "Utilization of Atmospheric Nitrogen for Agriculture and Industry." *Zeitschr. angew. Chem.*, **16**, 536.

ERLWEIN, G.: "A New Startling Material ($CaCN_2$) for the Preparation of Cyanides." *Ibid.*, **16**, 520, 533.

1905.

FRANK, A.: "Cyanamide." *Zeitschr. angew. Chem.*, **18**, 1734.

1906.

CARLSON, F.: "New Method for the Manufacture of Cyanamide." *Chem. Ztg.*, **30**, 1261.

ERLWEIN, G.: "The Manufacture of Cyanamide." *Zeitschr. Elektrochem.*, **12**, 551.

FRANK, A.: "The Direct Utilization of Atmospheric Nitrogen." *Zeitschr. angew. Chem.*, **19**, 835.

1907.

BREDIG, G.: "On Lime-Nitrogen." *Zeitschr. Elektrochem.*, **13**, 69.

BREDIG, G., HABENKEL, W., and WILKE, E.: "On Lime-Nitrogen." *Ibid.*, **13**, 605.

FOERSTER, F., and JACOBY, N.: "Formation of Lime-Nitrogen." *Ibid.*, **13**, 101.

KUHLING, O.: "Products Obtained from Alkaliearth Carbonates, Carbon and Nitrogen." *Ber.*, **40**, 310.

RUDOLFI, E.: "The Formation of Cyanamide and Calcium Carbonate." *Zeitschr. anorg. Chem.*, **54**, 170.

1908.

FRANK, A.: "Utilization of Atmospheric Nitrogen in the Production of Cyanamide." *Trans. Faraday Soc.*, **4**, 99.

KÜHLING, O., and BERKHOLD, O.: "Influence of Chloride Additions on the Reaction Between Barium Carbonate, Carbon and Nitrogen." *Ber.*, **41**, 28.

POLLACCI, G.: "Nitrogenizing Calcium Carbide." *Zeitschr. Elektrochem.*, **14**, 565.

1909.

CARO, N.: "Cyanamide Industries and Related Processes." *Zeitschr. angew. Chem.*, **22**, 1178.

FOERSTER, F., and JACOBY, H.: "Formation of Lime-Nitrogen." *Zeitschr. Elektrochem.*, **15**, 820.

KUHLING, O., and BERKHOLD, O.: "Action of Nitrogen on Commercial Barium Carbide." *Zeitschr. angew. Chem.*, **22**, 193.

1910.

ANON.: "Cyanamide Manufacture in France." *Times Eng. Suppl.*, Aug. 17th.

CARO, N., SCHÜCK, B., and JACOBY, R.: "Lime-Nitrogen." *Zeitschr. angew. Chem.*, **23**, 2405

COLLETT, D E., and ECKHARDT, M.: "Conversion of Cyanamide Into Nitrate of Lime." *J. Soc. Chem. Ind.*, **29**, 1010.

THOMPSON, M. DEK., and LOMBARD, R. H.: "Equilibrium of the System Consisting of Lime, Carbon, Calcium Carbide and Carbon Monoxide." *Met. Chem. Eng.*, **8**, 279, 324.

THOMPSON, M. DEK., and LOMBARD, R. H.: "Equilibrium of the System Consisting of Calcium Carbide, Cyanamide, Carbon and Nitrogen." *Ibid.*, **8**, 617.

1911.

BECKMANN, J. W.: "What is Cyanamide?" *Met. Chem. Eng.*, **9**, 12.

ERLWEIN, G., WARTH, C., and BEUTNER, R.: "Decomposition of Calcium Carbide by Heat." *Zeitschr. Elektrochem.*, **17**, 177.

LAMY, E.: "The Industrial Fixation of Nitrogen." *Met. Chem. Eng.*, **9**, 100.

LEBLANC, M., and ESCHMANN, M.: "The Formation and Decomposition of Cyanamide." *Zeitschr. Elektrochem.*, **17**, 20.

TUCKER, S. A., and MOODY, H. R.: "The Action of Nitrogen on Lithium Carbide." *J. Amer. Chem. Soc.*, **33**, 1478.

1912.

ANON.: "Cyanamide Production at Niagara Falls." *Oil, Paint and Drug Reporter*, July 29th.

1913.

ANON.: "Proposed Combination of the Ostwald Process for Making Nitric Acid From Ammonia With the Manufacture of Cyanamide." *Met. Chem. Eng.*, **11**, 438.

BODENSTEIN, M.: "Equilibrium Measurements Between Lime and Carbon and Between Calcium Carbide and Carbon Monoxide." *Chem. Ztg.*, **36**, 606.

PRANKE, E. J.: "Manufacture and Uses of Cyanamide." *Chem. Eng.*, **17**, 113; *J. Ind. Eng. Chem.*, **5**, 159.

WILDT, J. C. DE R. DE, *and* BERKHOUT, A. D.: "Cyanamide, Dicyanamide and Lime-Nitrogen." *Arch. Suikerind.*, **21**, 717.

1914.

ANON.: "Cyanamide and Nitrogen Products." *Engineering*, **98**, 267.

LOHNIS, E.: "Ammonification of Cyanamide." *Zeitschr. Gärhungsphysiol.*, **5**, 16.

MANUELLI, C.: "Transformation of Cyanamide into Ammonia." *Annali Chim., Appl.*, **1**, 388.

1915.

ANON.: "The Cyanamide Works at Niagara Falls." *Eng. News*, **73**, 16.

FRANK, A., and CARO, N.: "History of Lime-Nitrogen." *Chem. Ind.*, **38**, 445.

LANDIS, W. S.: "Fixation of Atmospheric Nitrogen. The Cyanamide Process." *J. Ind. Eng. Chem.*, **7**, 433.

WASHBURN, F. S.: "The Cyanamide Process." *Met. Chem. Eng.*, **13**, 309.

1916.

LANDIS, W. S.: "Production of Ammonia From Cyanamide." *J. Ind. Eng. Chem.*, **8**, 156.

1917.

ANON.: "Production of Cyanamide in France and Italy." *Rev. gén. Elec.*, **1**, 518.

ANON.: "Nitrate Supply Committee Recommendations on Synthetic Nitric Acid for the Government, With Reports on Various Methods." *J. Ind. Eng. Chem.*, **9**, 835.

KULLGREN, C.: "The Rate of Ammonia Production From Cyanamide." *Svensk. Kem. Tidskrift*, **29**, 40.

1918.

ZYL, J. P. VAN: "Alteration of Lime-Nitrogen on Storing." *Zeitschr. angew. Chem.*, **31**, 204.

COMBINATION WITH METALS TO FORM NITRIDES.

1862–1900.

AHRONS, L.: "The Formation of Aluminium Nitride in the Electric Arc Between Aluminium Electrodes." *Naturw. Rundschau*, **14**, 453 (1899).

BRIEGLEB and GEUTHER: "The Formation of Aluminium Nitride." *Ann. d. Chem.*, **123**, 228 (1862).

FRANK, L., and ROSSEL, A.: "Combustion of Powdered Aluminium With Finely Divided Calcium Carbide." *Chem. Ztg.*, **20**, 38 (1896); **21**, 263 (1897).

MALLET, J. W.: "The Preparation of Aluminium Nitride." *J. Chem. Soc.*, **30**, 349 (1876); *Ann. d. Chem.*, **186**, 155 (1877).

MATIGNON, C.: "Combustion of Pure Aluminium Powder in Air." *Compt. rend.*, **130**, 1390 (1900).

MOISSAN, H.: "The Presence of Aluminium Nitride in Commercial Aluminium." *Le four électrique*, 267 (1897).

1901.

EIDMANN, W., and MOESER, L.: "The Formation of Magnesium Nitride by Heating Magnesium in Air." *Ber.*, **34**, 390.

1903.

ZENGHELIS, C.: "Chemical Reactions at Very High Temperatures." *Zeitschr. Elektrochem.*, **9**, 698.

1906.

WHITE, A. H., and KIRSCHBAUM, L.: "Nitrides of Zinc, Aluminium and Iron." *J. Amer. Chem. Soc.*, **28**, 1343.

1907.

FICHTER, F.: "Aluminium Nitride." *Zeitschr. anorg. Chem.*, **54**, 322.

KAISER, K.: "Continuous Production of Ammonia." *Ger. Patent*, **181**, 657.

1908.

BECK, E.: "Preparation of Alloys of Nitride-Forming Metals (Fixation of Atmospheric Nitrogen)." *Metallurgie*, **5**, 504.

1909.

BRONNERT, E.: "Manufacture of Synthetic Ammonia (Serpek's Process)." *Bull. Soc. Ind. Mulhouse*, **79**, 39; *J. Soc. Chem. Ind.*, **28**, 433.

1910.

CARO, N., *et al.*: "Absorption of Nitrogen by Aluminium Carbide." *Zeitschr. angew. Chem.*, **23**, 2412.

LANDMARK, H. B.: "The Production of Titanium Nitride and Ammonia." Norwegian Patent No. 1,20199.

1911.

BOURGEREL, G. L.: "Aluminium Nitride, Alumina and Nitric Acid." *Mon. Sci.*, (v) **1**, II, 561.

1912.

MARRÉ, F.: "Fixation of Nitrogen by Means of Aluminium Nitride." *Génie Civil*, **61**, 30.

TUCKER, S. A., and READ, H. L.: "Fixation of Nitrogen by Alumina and Carbon." *Met. Chem. Eng.*, **10**, 745.

1913.

FRAENKEL W.: "On the Formation of Aluminium Nitride From Alumina Carbon and Nitrogen." *Zeitschr. Elektrochem.*, **19**, 362.

RICHARDS, J. W.: "The Serpek Process." *J. Ind. Eng. Chem.*, **5**, 335.

RICHARDS, J. W.: "Aluminium Nitride." *Trans. Amer. Electrochem. Soc.*, **23**,

ROSS, W. H.: "Decomposition of Feldspar and Its Use in the Fixation of Atmospheric Nitrogen." *J. Ind. Eng. Chem.*, **5**, 725.

RUSS, F.: "Experiment Demonstrating the Formation of Aluminium Nitride." *Zeitschr. Elektrochem.*, **19**, 923.

STÄHLER, A., and ELBERT, J. J.: "Fixation of Atmospheric Nitrogen by Means of Boron Compounds." *Ber.*, **46**, 2060.

TUCKER, S. A.: "Relation of the Production of Alumina to the Fixation of Nitrogen." *J. Ind. Eng. Chem.*, **5**, 191.

WOLF, J.: "The Preparation of Aluminium Nitride From Its Elements." *Zeitschr. anorg. Chem.*, **83**, 159.

1914.

ANON.: "Nitrides and the Synthesis of Ammonia." *Zeitschr. Ver. deutsch. Ing.*, **58**, 66.

MATIGNON, C.: "Synthesis of Ammonia by Means of Aluminium Nitride." *Chem. Ztg.*, **38**, 844, 909.

MOLDERHAUER, W., and GRÖBE, F.: "Iron and Chromium Nitrides." *Zeitschr. angew. Chem.*, **27**, 334.

SERPEK, O.: "Inorganic Synthesis of Ammonia." *Ibid.*, **27**, 41.

1915.

ASKENASY, P.: "Aluminium Nitride." *Zeitschr. angew. Chem.*, **28**, 621.

1917.

NORSKE NITRID ATK. (SERPEK): "Fixing Nitrogen." *Chem. Abstr.*, **11**, 1733.

1918.

MAXTED, E. B.: "Studies in Nitride Formation." *J. Soc. Chem. Ind.*, **37**, 105T.

NISSEN, O.: "The Serpek Nitride Furnace." *Chem. Met. Eng.*, **19**, 808.

CONVERSION TO CYANIDES.

1828–1894.

BUNSEN and PLAYFAIR: "Fixation of Nitrogen as Alkali Cyanides." *J. prakt. Chem.*, **42**, 397 (1847).

CASTNER, H. Y.: "Manufacture of Cyanides." *Eng. Patent*, 12,218 (1894).

DEFOSSES: "Action of Nitrogen on a Mixture of Carbon and Alkali or Alkaline Earth Hydroxides or Carbonates." *J. chim. phys.*, **14**, 280 (1828).

FOWNES: "Fixation of Nitrogen as Alkali Cyanides." *J. prakt. Chem.*, **26**, 412 (1842).

1903.

"Cyanid-Gesellschaft m. b. H., Berlin." Preliminary report on its activities in the domain of the manufacture of Cyanide and the utilization of Atmospheric Nitrogen. *Zeitschr. angew. Chem.*, **16**, 520.

ERLWEIN, G.: "A New Startling Material ($CaCN_2$) for the Preparation of Cyanides." *Zeitschr. angew. Chem.*, **16**, 533.

1905.

BOILEAU, A.: "Electric Manufacture of Cyanides and Nitrates." *Génie Civil*, **47**, 293.

1907.

KUHLING, O.: "Products Obtained From Alkali-Earth Carbonates, Carbon and Nitrogen." *Ber.*, **40**, 310.

1908.

KUHLING, O., and BERKHOLD, O.: "Influence of Chloride Additions on the Reaction Between Barium Carbonate, Carbon and Nitrogen." *Ber.*, **41**, 28.

1909.

KUHLING, O., and BERKHOLD, O.: "Action of Commercial Nitrogen on Barium Carbide." *Zeitschr. angew. Chem.*, **22**, 193.

1913.

EWAN, T., and NAPIER, T.: "The Fixation of Nitrogen by Mixtures of Barium Oxide and Charcoal." *J. Soc. Chem. Ind.*, **32**, 467.

1914.

LINDBLAD, A. R.: "Synthesis in the Electric Furnace of Cyanogen Compounds or Nitrogen Compounds." *Ger. Patent*, 293,904; *Chem. Abstr.*, **11**, 3180.

1915.

BUCHER, J. E.: "Fixation of Atmospheric Nitrogen as Cyanides." *Chem. Abstr.*, **9**, 129, 357, 1671, 2972.

1917.

ANON.: "Nitrate Supply Committee Recommendations on Synthetic Nitrogen for the Government, With Reports on Various Methods." *J. Ind. Eng. Chem.*, **9**, 829.

BUCHER, J. E.: "Fixation of Nitrogen." *J. Ind. Eng. Chem.*, **9**, 233.

1918.

MORIMOTO, Y.: "Fixation of Nitrogen as Cyanide." *Chem. Abstr.*, **13**, 363.

THE OXIDATION OF AMMONIA.

1839–1891.

CARIUS, L.: "Oxidation of Ammonia by Ozone." *Ber.*, **7**, 1481 (1874).

KUHLMANN: "Oxidation of Ammonia." *Ann. d. Chem.*, **29**, 281 (1839).

WARREN, H. N.: "A Novel Method for the Production of Sodium and Potassium Nitrite." *Chem. News*, **63**, 290 (1891).

1903.

OSTWALD, W., and BRAUER: "The Catalytic Oxidation of Ammonia." *Chem. Ztg.*, 459.

1904.

TRAUBE, W., and BILTZ, A.: "The Production of Nitrites and Nitrates by Electrolytic Oxidation of Ammonia in the Presence of Cupric Hydrate." *Ber.*, **37**, 3130.

1905.

TRAUBE, W.: "Contribution to the Knowledge of the Electrolytic Oxidation of Ammonia." *Ber.*, **38**, 828.

1906.

OSTWALD, W.: "The Production of Nitric Acid From Ammonia." *Berg. u. Hüttmann Rundschau*, Dec. 20.

SCHMIDT, O., and BÖCKER, R.: "Oxidation of Ammonia." *Ber.*, **39**, 1366.

TRAUBE, W. and BILTZ, A.: "Production of Nitrites and Nitrates by the Electrolytic Oxidation of Ammonia in the Presence of Cupric Hydroxide." *Ber.*, **39**, 166.

1908.

ORLOW, E.: "Oxidation of Ammonia by Means of Contact Substances." *J. Russ. Phys. Chem. Soc.*, **40**, 659.

WOLTERECK, H. C.: "Synthesis of Ammonia." *Compt. rend.*, **146**, 124.

1909.

BROCHET, A., and BOITEAU, G.: "Electrolytic Oxidation of Ammonia." *Bull. Soc. Chim.*, (iv) **5**, 667.

1910.

FRANK, A., and CARO, N.: "Preparation of Nitric Acid From Ammonia by the Contact Process." *J. Soc. Chem. Ind.*, **29**, 1010.

1912.

KOCHMANN, W.: "The Catalytic Oxidation of Ammonia." *Arb. Pharm. Inst.*, Berlin, **8**, 81.

MENEGHINI D.: "Catalytic Oxidation of Ammonia." *Gazzetta*, **42**, 126.

REINDERS, W., and CATS, A.: "Oxidation of Ammonia." *Chem. Weekblad*, **9**, 47.

1913.

ANON.: "The Ostwald Process for Making Nitric Acid From Ammonia. Its Proposed Combination with the Manufacture of Cyanamide." *Met. Chem. Eng.*, **11**, 438.

MENEGHINI, D.: "Catalytic Oxidation of Ammonia." *Gazzetta*, **43**, 81.

1914.

DIEFFENBACH, O.: "Conversion of Ammonia Into Nitric Acid or Ammonium Nitrate, From an Economic Standpoint." *Chem. Ind.*, **37**, 265.

DONATH, E.: "Conversion of Ammonia Into Nitric Acid or Ammonium Nitrate, From an Economic Standpoint." *Ibid.*, **37**, 513.

MOLDENHAUER, W., and WEHRHEIM, O.: "Catalytic Conversion of Ammonia Hydrocyanic Acid and Cyanogen to Nitric Oxide." *Zeitschr. angew. Chem.*, **27**, 334.

OESTERHELD, G.: "Electrolytic Oxidation of Ammonia." *Zeitschr. anorg. Chem.*, **86**, 105.

1916.

ANDERSON, E. B.: "Catalytic Oxidation of Ammonia." *Zeitschr. Elektrochem.*, **22**, 441.

ANON.: "Nitrogen Oxides From Ammonia by the Lead Chamber Process." *Engineering*, **102**, 440.

KAISER, K.: "Conversion of Ammonia Into Nitric Acid." *Chem. Ztg.*, **40**, 14.

LANDIS, W. S.: "Oxidizing Ammonia" *Chem. Abstr.*, **10**, 2505.

PETERSEN, H.: "Nitric Acid From Ammonia." *Metall. u. Erz*, **13**, 197.

SCHÜPHAUS, G.: "Production of Nitric Acid From Ammonia." *Metall. u. Erz.*, **13**, 21.

ZIESBERG, F. C.: "The Ostwald Process for Oxidizing Ammonia to Nitric Acid." *Met. Chem. Eng.*, **15**, 299.

1917.

ANON.: "The Manufacture of Nitric Acid by the Oxidation of Ammonia." *Elettrotecnica*, **4**, 102.

ANON.: "Nitrate Supply Committee Recommendations on Synthetic Nitric Acid for the Government, With Reports on Various Methods." *J. Ind. Eng., Chem.*, **9**, 837.

BUSVOLD, N.: "Oxidizing Ammonia." *Chem. Abstr.*, **11**, 1891.

DONATH, E.: "Production of Nitric Acid From Ammonia." *Zeitschr. Schiess-Sprengstoffw.*, **11**, 172.

FOX, P. J.: "Chemical Control of Ammonia Oxidation." *J. Ind. Eng. Chem.*, **9**, 737.

MAXTED, E. B.: "Synthesis of Ammonia and Its Oxidation to Nitric Acid." *J. Soc. Chem. Ind.*, **36**, 777.

1918.

LILJENRTH, F. G.: "Starting and Stability Phenomena of Ammonia Oxidation." *Chem. Met. Eng.*, **19**, 287.

PARTINGTON, J. R.: "The Oxidation of Ammonia." *J. Soc. Chem. Ind.*, **37**, 337R.

PRANKE, E. J.: "Development in Nitric Acid Manufacture in the United States Since 1914." *J. Ind. Eng. Chem.*, **10**, 330.

TAYLOR, G. B., and CAPPS, J. H.: "Effect of Acetylene on the Oxidation of Ammonia to Nitric Acid." *J. Ind. Eng. Chem.*, **10**, 457.

WENGER, P., and URFER, C.: "Study of the Oxidation of Ammonia in the Presence of Platinum and Rhodium." *Ann. chim. anal.*, **23**, 97.

1919.

FAIRLIE, A. M.: "Muscle Shoals Nitrate Plant." *Chem. Met. Eng.*, **20**, 8.

TAYLOR, G. B., and CAPPS, J. H.: "Effect of Phosphine and Hydrogen Sulphide on the Oxidation of Ammonia to Nitric Acid." *J. Ind. Eng., Chem.*, **11**, 27.

DEPARTMENT OF CHEMISTRY,
SWARTHMORE COLLEGE,
SWARTHMORE, PA.
March 26, 1919.

Speculum Metal. ANON. (*Brass World*, vol. xv, No. 5, p. 147, May, 1919.)—If two parts of copper and one of tin are mixed, it makes a white alloy which has a brilliant lustre, and will take a high polish. This alloy is known as speculum metal, the technical name for telescope mirrors or reflectors. The addition of one or two per cent. metallic arsenic makes the metal more compact and gives it a greater lustre and hardness, but renders it liable to be tarnished. It is nearly as hard as steel and as brittle as sealing wax.

Qualities of Steel for Guns. ANON. (*Machinery*, vol. xxv, No. 9, p. 835, May, 1919.)—The metallurgy of gun steel has been greatly altered as a result of the war. As the war drew to a close, steel for large guns was being made in a radically different manner than had ever been thought possible. It was an accepted fact four years ago that only acid open-hearth steel could be safely incorporated in ordnance guns, and the plants especially built in this country adopted this process. The reason for this policy was that it is possible by this process to make unusually pure and reliable metal, and it was thought that this was the only method by which this was possible. The great disadvantage involved is the length of time to produce a heat of such steel. In all such work the complete deoxidation, the formation of the proper slags, and the refinement of the metal consume from thirteen to fifteen hours in the case of a forty- or fifty-ton heat with the utmost care necessary. As the development of the ordnance program progressed, it was found that the large electric furnace refining hot metal on a basic bottom produced gun steel equal if not superior to that made by the long-drawn-out acid open-hearth process.

While a three per cent. nickel steel was the standard alloy incorporated in many of the guns, it is stated that at a large British plant a plain carbon electric steel was giving entire satisfaction in the last months of the war. It is also reported that in one American plant gun steel that met ordnance specifications satisfactorily was being made in basic open-hearth furnaces—a steel that was tabooed for guns before the war and later. It is probably a fact that had the war continued much longer, the electric furnace would have been the first selected as the agent with which to make ordnance steel. It was even being scheduled for one of the later plants, and this is so, not so much perhaps because of the superiority in quality over acid open-hearth, but because the same amount of suitable metal can be made in about one-third the time.

Vegetable Oils. ANON. (*The Chemical Engineer*, vol. xxvii, No. 2, p. 30, February, 1919.)—Government restrictions on the export of vegetable oils, coupled with what is apparently an over-production of oil, the result of the stimulus of war-time conditions and prices, has resulted in the production of a paradoxical condition in the industries producing or handling vegetable oils. While there is a strong demand for fats of all kinds over wide areas in Europe, with good prices offering, the American market is glutted with vegetable oils. Not only is this condition of affairs causing American dealers and manufacturers a great deal of inconvenience, but the holders of large stocks of raw and refined oils are threatened, if the present condition of affairs continues for any length of time, with serious losses through the deterioration of the oil. Further, according to those well acquainted with the situation, there exists a very real danger that the existing export market for American surplus oil and oil products may be lost during the period over which the import restrictions hold good.

AN APPLICATION OF THE RADIOMETER TO THE MEASUREMENT OF ELECTRIC CURRENT.*

BY

THOMAS D. COPE, Ph.D.

Assistant Professor of Physics, University of Pennsylvania.
Member of the Institute.

THE radiometer was discovered by Crookes [1] about 1875, and was used by him to measure radiant energy. In 1883 Pringsheim [2] applied a form of the instrument to the study of the infra-red spectrum of the sun. In 1897 E. F. Nichols [3] produced the first highly sensitive and accurate radiometer. He applied it to the study of the transmission and reflection of radiation by quartz, and subsequently to the study of radiation received upon the earth from planets and fixed stars. Nichols and Hull [4] applied the radiometer to the study of light-pressure. Stewart [5] has applied the instrument to the study of radiation from acetylene flames. Drew [6] has used it to measure the energy radiated from vacuum-discharge tubes. Coblentz has reviewed measurements of radiation made by himself and others, together with the significant facts about the instrument in the Bulletin of the Bureau of Standards, vol. iv, No. 3.

The suggestion to apply the radiometer to the measurement of electric current was made by Dr. C. E. Hiatt, formerly Harrison Research Fellow in Physics at the University of Pennsylvania. To try out his suggestion he constructed a radiometer with two vanes, each of which faced a thin metallic strip which was connected by electric leads to binding posts outside of the vacuum chamber. Each strip when heated by the passage of

* Communicated by the Author.

[1] *Phil.Trans.* (II), **166**; p. 325, 1876.

[2] *Ann der Phys.* (3), **18**; p. 32, 1883.

[3] *Phys. Rev.*, **4**; p. 297, 1897.

[4] *Phys. Rev.*, **13**; 1901; p. 307.

[5] *Phys. Rev.*, **13**; 1901; p. 257.

[6] *Phys. Rev.*, **17**; 1903; p. 321.

current through it would, it was thought, repel the vane facing it. The geometrical relations of heaters and vanes were such that the torques applied to the radiometer suspension by the heaters would be oppositely directed. If the two heaters were joined in series and a current were sent through them a "zero" position of the suspension would be established. If then a current of unknown strength were sent through one heater and an easily measurable current were sent through the other and the latter were varied in intensity until the suspension should assume its zero position the intensity of the known current would equal the effective value of the intensity of the unknown.

As Doctor Hiatt was prevented from continuing the investigation the radiometer was turned over to the writer by Professor A. W. Goodspeed with the suggestion that the work be continued. The instrument as first designed was found after repeated tests to be unsatisfactory. It was abandoned and a new form was designed and constructed, as described in the following:

A glass vessel was blown approximating a right circular cylinder with rounded convex ends. It was 30 centimetres long and 10 centimetres in diameter. When in use it stood with its axis vertical. It was provided with four orifices. One of the latter, coaxial with the vessel at the bottom, led through a stop-cock and ground-joint to a von Reden pressure gauge and through a drying-vessel which contained phosphorus pentoxide to a Geissler air-pump. A ground-joint coaxial with the vessel at the top, 16 millimetres at its greatest diameter, admitted a ground stopper which was prolonged into a rod 4 centimetres long from which the radiometer was suspended. The other two orifices were coaxial ground joints. Their common axis was a prolonged diameter of the vessel, distant approximately 14 centimetres from the top. These joints tapered from an exterior diameter of 3.6 centimetres to a diameter of 3.3 centimetres where they entered the vessel. Each was 4 centimetres long. Each was provided with a hollow stopper provided with a handle. Through the stoppers were sealed platinum leads. Each stopper supported a mica frame which carried a current-bearing heater. To the top of the vessel was attached externally and coaxial with it a horizontal disk 6 centimetres in diameter whose limb was graduated in degrees. Over this circular scale moved a pointer rigidly attached to the stopper in the upper ground joint.

The radiometer suspension was supported by a quartz fibre 9 centimetres long and one-seventieth of a millimetre in diameter. It hung along the axis of the containing vessel from the glass rod, to which it was attached. It supported a small stirrup which in turn held a horizontal aluminum wire 9 centimetres long and 0.5 mm. in diameter. To this wire were attached, each in the vertical plane through the wire, centrally a light wire carrying a circular plane mirror about one centimetre in diameter, and flush with each end a rectangular vane of mica, 3.5 cm. horizontally by 3 cm. vertically.

The heaters were wound on opposite faces of vertical mica frames. Platinum wire 0.1 mm. in diameter was used. The frames were supported in the lateral ground stoppers. Each heater faced a vane of the suspension in such a way that the turning moments given to the suspension by the two heaters were similarly directed. The area of a vane was somewhat greater than the area covered by the heater which it faced. The heater wire was soldered to copper leads which in turn were soldered to platinum leads through the glass. The two heaters were joined in series in circuit with a storage cell, an adjustable resistance and a Siemens and Halske milliameter. The circuit was connected to the water pipe system of the building to remove possible static changes.

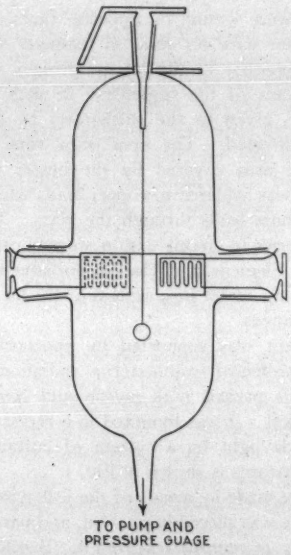
The instrument was supported by appropriate stands and clamps and was protected from external radiation by close-fitting card-board shields packed with cotton and covered externally by a sheet of tinfoil. It was mounted in a recess in the wall and protected from daylight by a system of curtains. A vertical section of the apparatus is shown in Fig. 1.

Readings were made by means of the following arrangement: A millimetre scale was placed horizontal, and parallel to the mirror approximately 45 centimetres from it. Beneath the scale was placed a vertical slit illuminated by a 2-volt miniature lamp. A lens of 40-cm. focal length, 40 cm. from the scale, threw an image of the slit reflected from the mirror of the suspension upon the scale. A null method was used in making measurements. The readings taken when current flowed through the heaters were the number of degrees through which the torsion head of the instrument had to be turned to bring the suspension to its position

of equilibrium when no current was flowing in the heaters. This position was indicated by a chosen " zero position " of the image of the slit on the scale.

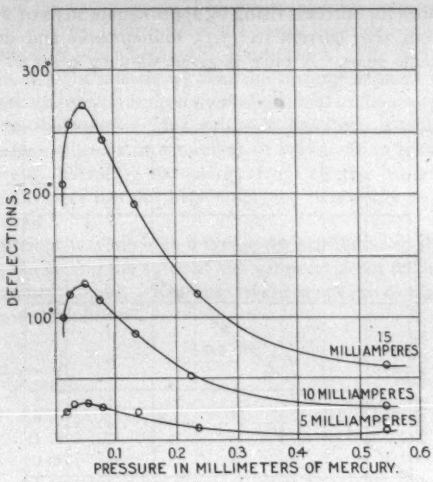
Measurements were made with the instrument for the purpose of determining the pressure at which the sensibility was a maximum. Readings were taken of the deflections arising from cur-

FIG. 1.



rents of 5, 10, and 15 milliamperes in the heaters at pressures ranging from 1 mm. to 0.01 mm. The order of readings was 0, 5, 10, 15, 10, 5, 0 milliamperes. A table of data and a curve showing the results of this investigation are given in Table I and Fig. 2. This investigation shows the existence of a pronounced maximum of sensibility at a pressure between 0.03 and 0.035 mm. of mercury. Several sets of readings all leading to the same

FIG. 2.



result were taken. The set given was the final and most satisfactory one.

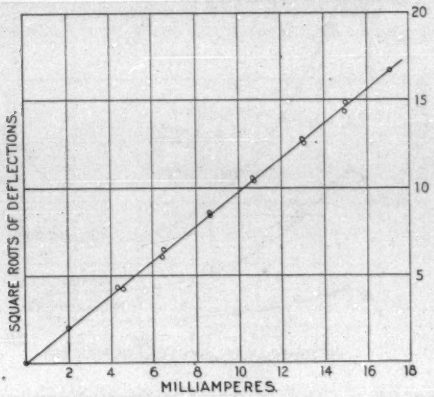
TABLE I

Pressure (m.m.)	Deflection (degrees on torsion head)				
	5	10	15	10	5 milliamperes
2.08	.....	7	16	7	1.5
1.07	4	15.5	34	16	4
0.544	6.5	27.5	61	29	7.5
0.235	12	52	117	52	12
0.131	23	84	193	85	23.5
0.0697	26	111	245	111	26
0.0381	31.5	125	272	125.5	31
0.0187	31	120	265	121	31
0.0185	29.5	117.5	255.5	119.5	29.5
0.0096	24	100	207	99	25

In the region of maximum sensibility the instrument was calibrated. The pressure used was 0.0378 mm. of mercury. Readings were taken of the current in the heaters and the deflection

of the vanes for currents rising by approximate steps of 2 milliamperes from zero current to 17.15 milliamperes and decreasing by the same steps. A table is given showing a set of observa-

FIG. 3.



tions, together with a curve in which square roots of deflections are plotted against currents.

TABLE II

Pressure 0.0378 millimeters		
Current (milliamperes)	Deflection (degrees)	Square root of deflection
2.0	4	2
4.25	18	4.24
6.4	37.5	6.12
8.7	71	8.42
10.9	111	10.5
13.0	157	12.5
15.1	212	14.5
17.15	275	16.6
15.1	220	14.8
13.0	159	12.6
10.8	113	10.6
8.7	72.5	8.51
6.5	42	6.48
4.3	17.5	4.18
2.0	4	2

Since the same geometrical relations existed between the heaters and the vanes facing them when readings were taken, the amount of energy falling upon the vanes depended only on the rate at which it was liberated in the heaters. The fact that the curve is a straight line shows that the turning moment upon the radiometer suspension is directly proportional to the energy which falls upon the vanes. This principle has been established by previous investigators in a number of ways. It is believed that the device of liberating the energy from electric heaters within the vacuum space has not been employed heretofore to establish this principle.

An attempt was made to increase the sensibility of the instrument by blackening the faces of the vanes adjacent to the heaters with camphor smoke. Readings were made at a pressure of 0.0297 mm. as follows:

TABLE III

Current in milliamperes	Deflection in degrees
5	29
10	115
15	243
10	116
5	30

These deflections are of the same order of magnitude as those obtained under like conditions with unblackened vanes, and show no rise in sensibility arising from the blackening. Measurements made of the resistance of the two heaters in series when currents of various intensities were flowing through them gave the following results:

Resistance of heaters	Current in heaters
14.54 ohms	0.6 milliamperes
14.56 ohms	15.0 milliamperes

In conclusion, there is to be pointed out the possible usefulness of the principle employed in this instrument in an indicator of effective values of currents of rapidly varying direction and intensity. Its use in circuits containing spark gaps in which the added resistances of the heaters would be apprciable is suggested. The instrument is usable only when thoroughly shielded from radiation and mechanical vibration. In common with other hot

wire instruments it has the disadvantages of a complicated construction and rather sluggish action in reaching its final reading.

It was the plan of the writer to redesign the apparatus with a view toward determining the effective values of currents of unknown intensity by balancing the torques given by them to the radiometer suspension by the torques arising from direct currents of known intensity. At this stage the work was interrupted and opportunity to continue it has not since existed.

RANDALL MORGAN LABORATORY OF PHYSICS,
UNIVERSITY OF PENNSYLVANIA.

A New Seed Oil from Cockle Burr. L. B. RHODES. (*American Chemical Society News Service, Bulletin No. 231*, May 4, 1919.)—Out of the cockle burr which sticks to the clothes of the passer-by and has generally been considered a pest, is now being made a new and valuable oil available for use in paints and varnishes and adapted for food. The "cockle-burr," familiarly known as the "clot-burr," is a coarse plant with rough leaves and prickly head. It is widely distributed through the United States so that it is more or less of a nuisance in most localities, and is very abundant throughout the South. If the burrs could be obtained systematically in sufficiently large quantities, they could be easily milled.

Those which were gathered were either dry or in a half-dry condition. They were first cut in half by a trimming board and the kernels mashed. They were then placed in a box and vigorously shaken. The hulls were taken out, leaving the kernels at the bottom. These kernels were then pounded and rubbed in a mortar until the black shucks were removed after which the husks were forced out by blowing. The ground kernels were then wrapped in cheese cloth and pressed between cold steel plates. The oil thus obtained was allowed to settle for three or four days and then filtered. It is of a light yellow shade; has a clear sparkling appearance and a pleasant odor and an agreeable nutty taste. It keeps well without becoming rancid. On account of this quality it should eventually be used as a substitute in the dietary for other vegetable oils. The press cake left after expressing the oil should be of value as a food for cattle and certainly it can be readily used as a fertilizer.

There seems no doubt that before long the cockle burr oil should find a place in commerce because of the richness of the kernel and ease with which the oil can be extracted. The yield from the kernel is about 30 per cent. and the kernels constitute about the same proportion of the bulk of the crude burrs. The press cake contains 40.34 per cent. of protein. With such in their favor the familiar roadside pests may prove of real service to both man and beast.

NOTES FROM THE U. S. BUREAU OF STANDARDS.*

NEW FORMS OF INSTRUMENTS FOR SHOWING THE PRESENCE AND AMOUNT OF COMBUSTIBLE GAS IN THE AIR.[1]

By E. R. Weaver and E. E. Weibel.

[ABSTRACT.]

A STUDY has been made of the combustion of small amounts of gas in the air at the surface of electrically heated wires and the application of this phenomenon to the design of instruments for the purpose of detecting the presence and indicating the amount of combustible gas in the air. As a result of this study three types of instruments, each especially adapted to certain uses, have been designed, tested, and found to work satisfactorily.

The action of one of these instruments depends upon a resistance change, one upon a heating effect upon an adjacent bimetallic strip, and one upon the light emitted from the heated wire.

A discussion of the principles involved in the design of the instruments and specifications for their construction are given.

SPECIFICATIONS FOR AND METHODS OF TESTING SOAPS.[2]

[ABSTRACT.]

THIS circular includes a general discussion of the composition of soap and the varieties of toilet, laundry, scouring and soft soaps for which specifications are proposed. These specifications cover milled toilet soap, white floating soap, liquid soap, shaving soap, salt-water soap, special-grade laundry soap, ordinary-grade laundry soap, chip soap, soap powder, hand grit soap, scouring soap (A), scouring soap (B) and automobile soap. The methods described include those for sampling deliveries, for preparation of the laboratory sample and for the following tests and determinations: Matter volatile at 105° C.; free alkali or acid; alkali as alkaline salts; silicate; sulphate; matter insoluble in water

* Communicated by the Director.

[1] Scientific Papers, No. 334.

[2] Circular No. 62, 2d edition.

(insoluble siliceous material); unsaponified saponifiable matter; preparation of total fatty acids; titer test; acid number of fatty acids; total alkali; chloride; rosin; total anhydrous soap; sugar (qualitative test); feldspar and quartz; potash and soda.

EFFECT OF SOLAR RADIATION UPON BALLOONS.[3]

By Junius David Edwards and Maurice Blaine Long.

[ABSTRACT.]

THIS paper describes briefly the effect of solar radiation upon balloons and includes experimental measurements on typical balloon fabrics.

Preliminary to the subject proper a summary is given of the characteristics of solar radiation and atmospheric conditions which have a direct relation to the problem. The radiation characteristics of the fabrics themselves are discussed. A series of measurements on representative balloon fabrics showed an absorbing power for solar radiation varying from 45 to 90 per cent.

The fundamental relations governing the temperature of balloon fabrics when exposed to solar radiation are outlined and the application of these to the calculation of balloon temperatures is discussed. The multiplicity of factors involved makes the calculation of such temperature of very limited value, but by means of measurements on a model balloon the magnitude and distribution of the temperatures involved, in both gas and fabric, are well illustrated. The temperature of the upper surface of the model balloon in bright sunlight under certain definite conditions, varied from 20° C. to 39° C.

The importance of the radiation characteristics of fabrics in governing buoyancy changes, in causing increased permeability of the fabric to hydrogen and in its effect on the life of the fabric is emphasized as a factor in the selection of fabrics for various purposes. Other factors affecting the selection of fabrics are summarized and their relation to the radiation characterisics is pointed out.

---

[3] Technologic Papers, No. 138.

NOTES FROM THE RESEARCH LABORATORY, EASTMAN KODAK COMPANY.*

REFINEMENTS IN SPHEROMETRY.[1]

By G. W. Moffitt.

THE shortcomings of the ring spherometer are discussed and a new type of contact ring with selected ball bearings for contact members, giving greater precision and reliability, is described. A modified instrument having but one contact is also described. It has certain advantages in some cases.

The auto-collimating method, as often used, is limited in its precision because of the depth of focus of the optical system. The improvement described consists in placing the lens on a nodal slide and adjusting until lateral motion of the image in the field of view is no longer noticeable when the slide is rotated through an angle. In the caustic curve methods use is made of the aberrations introduced on oblique reflection from a spherical surface. By measuring the distance from the primary to the secondary image and multiplying by a factor depending upon the arrangement of the apparatus the radius is determined with high precision for concave surfaces or convex surfaces of short radius. This method is especially valuable when the element of surface is small.

Surfaces measured with precision by the various methods described, are as follows: (1) Mechanical Methods: Concave and convex surfaces of short and medium radius, the precision decreasing rapidly as the radius becomes larger. (2) Auto-collimating Method: Concave and convex surfaces of short or medium radius up to the limit of the slide on the turntable, the precision being high and practically independent of the radius. (3) Caustic Curve Methods: Concave surfaces of any radius to a high degree of precision, even when the element of surface available is too small to be measured by other methods. Convex surfaces of short and medium radius to a degree of precision decreasing with increased radius.

* Communicated by the Director.

[1] Communication No. 78 from the Research Laboratory of the Eastman Kodak Company, published in *Physical Review*, vol. xiii, No. 4, p. 261.

Standardization of Aircraft Materials and Parts. ANON. (*Journal of the Society of Chemical Industry*, vol. xxxviii, No. 8, p. 144, April 30, 1919.)—It may not be generally known that during the past year and a half the British Engineering Standards Association has been responsible for the preparation of all specifications for aircraft materials on behalf of the Department of Aircraft Production. Particularly interesting have been those specifications dealing with materials which formerly were perhaps not considered as being of an engineering nature, such as chemicals used as ingredients for aeroplane dope, rubber, textiles, adhesives, paint and varnishes. Owing to the extremely useful part these specifications have played it is now learned with considerable satisfaction that the British Engineering Standards Association has been requested to continue to prepare them as well as to undertake their distribution, together with the issue of manufacturing instructions and notes on testing procedure which were formerly prepared and issued by the Technical and Inspection Departments of the Department of Aircraft Production. The Association has undertaken this additional responsibility as from March 31, 1919.

Phenol. A. G. PETERKIN. (*Journal of Industrial and Engineering Chemistry*, vol. xi, No. 5, p. 475, May, 1919.)—Before the war this country's consumption of phenol was about 9,000,000 pounds per year. The bulk of it came from England, and was obtained from coal-tar distillates directly. A small part was synthesized from benzol. The general impression here is that this synthetic phenol was made in German plants subsidized by the Government. The production in the United States during the war increased continually. At the time of our entry into the struggle it amounted to 75,000,000 pounds per year, and after that time plants were erected so that at the end we were able to produce more than 150,000,000 pounds. Of this, not more than 2,000,000 pounds were obtained directly from coal-tar distillates by extraction with caustic soda.

At the present time the consumption in this country is not much greater than 6,000,000 pounds per year, about equally divided between the drug and disinfectant, the dyestuff, and the synthetic resin industries.

Composite Ships. ANON. (*Marine Review*, vol. xlix, No. 6, p. 283, June 1919.)—The first Norwegian composite ship has been launched at Larvik. It is built of fir planks over a steel frame, has a carrying capacity of 650 tons and a speed of nine knots. It is driven by an oil motor and can carry a fuel supply to last twelve days. Another similar ship was launched in March. Denmark has a composite ship which was built recently at Frederickshavn.

NOTES FROM THE LABORATORY, GENERAL ELECTRIC COMPANY.*

A NEW METHOD OF DEVELOPING "GUM" PRINTS.

By C. S. Ferguson.

I BELIEVE the usual method for developing prints by the gum-bichromate process, particularly when it is desired to emphasize certain features, is to gently abrase the part intended to be accentuated by means of a camel's hair brush.

This procedure, as is well known, is likely to remove entirely the delicate film of gum unless extreme caution is exercised coupled with considerable manipulative skill.

I have found, I believe, a new technic which reduces manipulative skill to a minimum and which, at the same time, allows of local development to any desired degree without showing any obvious local treatment.

The print is first soaked in warm water. It is then supported against a piece of stout cardboard, as an easel, and sprayed with warm water from an atomizer. By having an ordinary photograph as a guide, one can so control the development of the image as to meet one's standard of art.

* Communicated by the Director.

The "Pipeless" Furnace. ANON. (*Metal Worker, Plumber and Steam-Fitter,* vol. xci, No. 19, p. 519, May 9, 1919.)—The so-called "Pipeless" furnace, by which the heating of an entire dwelling is effected through only one outlet on the first floor immediately above the furnace, has come into extended use within recent years. The very satisfactory results of the one-pipe apparatus are due to a double cased furnace with a duplex register face for the entrance of cool air as well as for the discharge of heated air. Equally good results can be obtained from the same furnace with the old style casing and independent registers and ducts for warm and return air supplies.

The success of any warm-air heating apparatus depends on the proper circulation of the air in the space warmed. If the air in such space is not moved or replaced, there will be no warm air flowing from the registers. While there are very many appar-

ently successful furnace plants, their economy is below par. This fact is demonstrated when a return air supply is installed. The return air system practically accomplishes exactly what the "pipeless" does. Such a condition is often found and disposes of the usual argument for more cold air. It also proves that some means must be provided for properly circulating the air to secure satisfactorily warm air plants.

The temperature at the register face of the one-pipe furnace is considerably higher than the ordinary register, and the velocity of the entering air is greater than from the common form of warm-air pipe. The high temperature and velocity combine to make the heating of almost any open or connected space a simple, quick and positive operation. Rooms on the second floor will be warmed so long as the doors are kept open, although distant rooms will suffer unless they open from a general hallway. The "pipeless" furnace supplies a need that has long existed for a simple and economical method of heating that does away with the objection of stoves, but it does not replace the desirable qualities of a good warm-air plant, properly piped and supplied with air, both from the house and from out of doors.

Department Store Testing Laboratory. ANON. (Dry Goods Equipment Through *Philadelphia Public Ledger*, May 9, 1919.)—What is probably the first research laboratory to be put in by any department store in the United States has been installed recently by the Bannon Brothers Company, St. Paul, Minn. This laboratory, completely equipped, and on the main floor in the textile department, actually makes practical and chemical tests of the textiles, food products, linoleums and other goods carried by the store. This has two advantages—it enables the buyers to know that the goods they buy are up to specifications with respect to quality, materials, and freedom from adulteration, and it enables the store to advertise its goods under a quality guarantee, backed by the evidence of its own laboratory.

The research laboratory consists of a glass-inclosed room, fitted out with the usual chemical laboratory equipment and in addition with special equipment for the testing of textiles and other products. The staff includes a trained chemist and two assistants, who make analyses of goods. Both microscopical and chemical tests are used. For accurate work in analyzing cloths the chemical test is necessary, but quick determinations that give approximate values can easily be made with a microscope.

The object of the laboratory is honesty in merchandising. The customer's interests are protected by checking and analyzing goods to see that they are as they are represented and that no misleading statements are made, especially in the papers. A test is made of every article advertised so that it can be truthfully presented as "pure silk" or "89 per cent. wool" with the backing of an actual test in the store's own laboratory.

NOTES FROM THE UNITED STATES BUREAU OF CHEMISTRY.*

PHOTOSENSITIZING DYES.

[ABSTRACT.]

THE photosensitizing dyes, *pinaverdol* and *pinacyanol*, which are used in the manufacture of panchromatic and orthochromatic plates, and which before the war were made exclusively in Germany, have now been synthesized in this country. The syntheses of these dyes, which are quinoline derivatives, are described in an article [1] by Wise, Adams, Stewart, and Lund, of the Color Laboratory of the Bureau of Chemistry. Two articles [2] describing the synthesis of the intermediates required for the formation of these dyes are published in the same issue of the same journal.

PARA CYMENE: II. THE UTILIZATION OF CYMENE FOR THE PREPARATION OF PHOTOGRAPHIC DEVELOPERS.[3]

By H. A. Lubs.

[ABSTRACT.]

LABORATORY methods for the production of para-amino-carvacrol have been worked out. This compound has been found to be very useful as a photographic developer. It is more satisfactory than para-amino-phenol, and while not quite so good as para-amino-cresol or "metol," so far as lasting quality of the bath is concerned, it is equally good with respect to quality of tones secured in the final prints.

* Communicated by the Chief of the Bureau.

[1] *J. Ind. Eng. Chem.*, 11: 460, May, 1919.

[2] *J. Ind. Eng. Chem.*, 11: 456, 458, May, 1919.

[3] Published in *J. Ind. Eng. Chem.*, 11: 455, May, 1919.

Domestic Electric Appliances. ANON. (*Electrical Review*, vol. lxxiv, No. 20, p. 808, May 17, 1919.)—Never before in the history of the electrical industry has there been such activity in the field of domestic electrical appliances as exists to-day. Practically all manufacturers report that their plants are working to capacity and central stations and dealers are doing an unusually large volume of business.

The reasons for this condition are obvious. In the first place the electrical appliance has become a household necessity. Also, the serious shortage in domestic labor has greatly stimulated the use of labor saving devices, as have the higher standards of living on the part of all classes of labor. Finally, central stations and dealers have made special effort to secure this class of business, especially since the restrictions were put into effect on practically all other business.

The saturation point is still far distant and efforts should be redoubled to increase the use of appliances under the favorable conditions existing to-day.

Applying the Brakes in Starting a Car. ANON. (*Electric Railway Journal*, vol. liii, No. 20, p. 964, May 17, 1919.)—One line of an electric railway was experiencing considerable trouble due to the blowing of circuit breakers. There were no excessive grades on this line and engineers of the company were somewhat puzzled to find a reason for such a phenomenon on one line while everything was apparently satisfactory on the others. Accordingly a man was detailed to watch the operation of the cars.

He discovered that there was a section of track which was very slippery and that the motormen had trouble in starting the light-weight cars at this point. They had received instructions to accelerate rapidly, which to them meant operating the controller rapidly. On this particular section of track it was the practice to notch up the controller very fast, and when the slipping point of the wheels had been reached to apply the brakes to keep the wheels from slipping. The reverse of this method was also found to have been applied in stopping the cars. The brake application produced a very rapid rate of retardation, and when the slipping point of the wheels was reached power was applied to prevent the wheels from skidding.

Petrol Substitute. ANON. (*The Iron Trade Review*, vol. lxiv, No. 21, p. 1355, May 22, 1919.)—Owing to the shortage of petrol in Greece consequent on the Allied blockade in 1916, a new petrol substitute was put on the market. It was composed of 80.90 per cent. of pure turpentine, distilled from resin from the pine forests of Greece, and 10.20 per cent. ether, which was also produced from native sources. The fuel was expensive and deposited a comparatively large amount of carbon in the cylinders, but this was easily removed.

NOTES FROM THE UNITED STATES BUREAU OF MINES.*

Vanadinite.—Experiments on the metallurgical treatment of vanadinite, with the object of recovering vanadium and lead, have been completed by the Golden Station of the Bureau. The arc furnace method was used to prepare ferrovanadium from calcium vanadate, containing only 16 per cent. of V_2O_5. Reductions made with aluminum gave better results than with silicon.

Ammonia in Producers.—A report on the quantity of ammonia in producers of the Smith type has been completed by the Seattle station. The use of Illinois coal in water-gas plants for producers of coal gas benches was studied at Rockford, Illinois. It was found that the use of this coal was an economy, although more coal was consumed per ton carbonized, smaller and more frequent changes are required and more attention is necessary than with coke as a fuel.

Oil Shale.—A bibliography of oil shale has been completed by the San Francisco Field Office. The work of collecting the data relative to the production and decline of the oil fields of California has been completed.

Geophone.—A study of the geophone, as developed for war purposes, to determine its applicability to surveying and mine rescue work in metal mines, was made at Franklin, N. J., in the mine of the New Jersey Zinc Company. Further work is being conducted at the Experimental Mine at Pittsburg on the instrument, which gives promise of value in mining not only in locating men entombed underground, but also as a warning to breaking through in a heading; in determining the direction underground of connections at drifts, tunnels, and raises without the use of survey instruments; for use in surveying diamond drill holes; for the location of underground water courses; and for use in counting shots fired underground. It has been found that sound is transmitted better through rock than through coal.

Mine Fires.—Valuable assistance has been rendered by the Bureau of Mines cars at recent mine fires. On March 4, in response to a call from the Hebron Fire and Pressed Brick Co.,

* Communicated by the Director.

Hebron, N. D., that they were unable to control a fire which threatened their lignite coal mine, Car 5 proceeded immediately to the place. The Bureau men wearing mine rescue apparatus were able to seal the fire, and possibly saved the mine. In a preliminary report the engineer in charge, Mr. Dyer, stated that there was a large German population at this place who were greatly impressed with the kindness of the government in thus aiding them.

On March 18 the Chamber of Commerce of Richey, Montana, wired that a fire in a local mine was beyond control and threatened their local coal supply and appealed for aid. Mr. B. W. Dyer was ordered to Richey. A letter of appreciation of the assistance given has been received from the Richey Chamber of Commerce. On February 25 a serious coal mine fire broke out at Somerset, Colo., and in response to call the engineer and Car 2 were sent there. On March 28 a serious fire broke out in the Argonaut Mine, near Jackson, Cal. Car 5, with District Engineer Wolflin, proceeded at once to the scene. No lives were lost, and serious property damage was prevented by quick action. On March 31, thirteen men were entombed and killed at an explosion at the Empire mines, Aguilar, Colo. Car 2 responded to the call.

Mine Rescue Cars.—The three new Bureau of Mines rescue cars, construction of which has been delayed on account of war conditions, will soon be completed. One of the cars will be ready by May 15 and the remaining two by July 1. These cars are to be stationed at Terre Haute, Ind.; Ironwood, Mich.; and Rock Springs, Wyo. The cars are to be of the new model and well equipped in every way.

THE FRANKLIN INSTITUTE.

(Proceedings of the Stated Meeting held Wednesday, May 21, 1919.)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, May 21, 1919.

PRESIDENT DR. WALTON CLARK *in the Chair.*

By consent of the meeting the reading of the minutes of the previous meeting was dispensed with.

Additions to membership since last report: 1.

The chairman announced that the business of the meeting would be the annual presentation of The Franklin Medal, the Institute's highest award, in recognition of distinguished scientific and technical achievements, and called upon Dr. Harry F. Keller, who gave an account of the work of Sir James Dewar, of the University of Cambridge, and the Royal Institution, London, recently recommended by the Institute's Committee on Science and the Arts for The Franklin Medal in recognition of "His numerous and most important contributions to our knowledge of physical and chemical phenomena, and his great skill and inventive genius in attacking and solving chemical and physical problems of the first magnitude."

Doctor Keller then presented Major General James Douglas McLachlan, C.B., D.S.O., representative of His Britannic Majesty's Government, who received the medal for Sir James Dewar, and conveyed the thanks of his Government and of the recipient for the honor conferred upon him.

Doctor Keller was again recognized and described the work of Major General George Owen Squier, who had also been recommended for the award of The Franklin Medal in recognition of "His valuable contributions to physical science, his important and varied inventions in multiplex telephony and telegraphy and in ocean cabling, and his eminent success in organizing and directing the air and signal services of the United States Army in the World War," and introduced Dr. F. P. Keppell, Assistant Secretary of War, who, in the absence of Major General Squier, received the medal on behalf of the recipient and the War Department.

Colonel C. McK. Saltzman, Acting Chief Signal Officer, United States Army, then read a paper, entitled "Some Aspects of the Signal Corps in the World War," which had been prepared by Major General Squier for presentation on this occasion.

Lantern slides and moving pictures showing the activities of the Signal Corps with the American Expeditionary Force were shown, as well as various Signal Corps communicating devices.

Adjourned.

R. B. OWENS,
Secretary.

(A full account of the meeting will appear in the next issue.)

COMMITTEE ON SCIENCE AND THE ARTS.

(Abstract of Proceedings of the Stated Meeting held Wednesday, May 7, 1919.)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, May 7, 1919.

MR. BENJAMIN FRANKLIN *in the Chair.*

The following report was presented for final action:

No. 2728: Landreth's Electrolytic Sewage Process. Recommended that the Howard N. Potts medal be awarded to Clarence P. Landreth, of Philadelphia, Pa.

R. B. OWENS,
Secretary.

ANNUAL REPORT OF THE DIRECTOR OF THE SCHOOL.

1918–19.

COURSES OF INSTRUCTION.

THE ninety-fifth year of the Franklin Institute School of Mechanic Arts closed May 2, 1919. During the year instruction was given in Mechanical Drawing, Architectural Drawing, Shop Arithmetic and Algebra, Plane Geometry and Trigonometry, Applied Mechanics and Strength of Materials, and Naval Architecture.

REGISTRATION.

The total registration for the year was four hundred seven individual students, approximately the same as the enrollment of the previous year. The call of their country to service in the World War prevented many former students from continuing their courses during the past year.

ATTENDANCE AND PROGRESS.

For the first term twenty-three students had a perfect attendance record, and fifty-three had a perfect attendance record during the second term. In the regular school work twenty-seven students made an average of 90 per cent. or over during the first term, and thirty an average of 90 per cent. or over during the second term.

The work of the school was seriously interrupted in the early part of the year by the influenza epidemic. Also, much of the time of the students was taken up by the unprecedented activity of the industrial plants in which a majority of them were employed, and this prevented them from attending their classes regularly. Considering these handicaps, the high averages in class work and attendance records indicate that the School of Mechanic Arts has completed a successful year.

FACULTY.

The corps of Instructors consisted of men of practical experience in the work in which they instructed and with a thorough knowledge of pedagogical principles.

SCHOLARSHIPS.

Twenty scholarships were available for students of the School; ten of these were Bartol Scholarships in Drawing, derived from the B. H. Bartol Fund; ten scholarships were derived from the Isaac B. Thorn Fund, and were awarded to students in Mathematics and Naval Architecture.

PRIZES.

Valuable prizes were offered by the following gentlemen for meritorious work in various departments:

Mr. Samuel M. Vauclain, Vice-President, The Baldwin Locomotive Works.

Mr. J. B. McCall, President, Philadelphia Electric Co.

Mr. Wilfred Lewis, President, Tabor Manufacturing Co.

Mr. J. T. Wickersham, Secretary and Treasurer, The New York Shipbuilding Corporation.

Mr. Robert W. Lesley, Past-President, Portland Cement Association and Member of the Board of Managers of The Franklin Institute.

The Alumni Association continued its special prizes to the graduates having the best records and to graduates having a perfect attendance for the year.

HONORS.

Certificates for the satisfactory completion of a course in one of the Departments of Drawing or Mathematics were this year awarded to thirty-five students. There were no graduates in the Department of Mechanics and Naval Architecture, due in the former instance to the unusual demand of the government during the past two years for men with any knowledge whatever of engineering, and in the latter instance, to the extension of the course to include three years of instruction instead of two years as in the past. Appended are the names of the graduates, also the names of those students to whom are awarded the scholarships and prizes indicated above, and the names of those students granted certificates of Honorable Mention for regularity of attendance and proficiency in class work.

The success of the year that has just closed is due not only to the earnestness of the students and their continued application to the work assigned, but also to the close personal attention and sympathetic interest of the instructors.

Respectfully submitted,

LOUIS C. ROBINSON,
Director.

May 9, 1919.

LIST OF GRADUATES, 1918-'19.

CERTIFICATES

Certificates on the Satisfactory Completion of Full Courses are Awarded as Follows:

MECHANICAL DRAWING.

Samuel Alberti
Samuel H. Collins
Israel Cramer
Francis A. Harden
George Hiddeman, Jr.
James Linton
Edward E. Loesch
Paul L. Mentzer
John Mitchell
George Nairn

Oliver Patton
John Pollano
Frederick G. Spellier
Nelson S. Troughton
George F. Weber

ARCHITECTURAL DRAWING.

James Ballantyne
Roy Douglas
Charles F. Linder

MATHEMATICS.

B. Newton Barber
Walter Bird
James Cogan
J. K. Depuy
Charles W. Earley
Anthony R. Finnigan
Herbert Jacobs
Alfred J. Kautter
Joseph Kroulik
John McClelland
Julius A. Meister
James L. O'Neill
Herman Schaaf
Wilson D. Scott
William Lee Smith
Stanley K. Weber
Benjamin A. Wilson

BARTOL SCHOLARSHIPS.

DEPARTMENT OF DRAWING.

Mathew Alexy
Mechanical
Walter Bruhns
Architectural
Louis S. Carroll
Mechanical
William E. Green
Mechanical
Frederick P. Klein, Jr.
Mechanical
Edwin C. Kunze
Mechanical
Paul T. Morrison
Mechanical
Joseph D. Quinn
Mechanical
William J. Reed
Free Hand
Thomas P. Walker
Mechanical

THORN SCHOLARSHIPS.

DEPARTMENT OF MATHEMATICS.

Harry Brick
Frank Cohen
H. L. Evers
William J. Haessler
C. R. McCormick
Charles A. Schuler
Harold Turner
Charles Walker

DEPARTMENT OF NAVAL ARCHITECTURE.

J. S. Herbine
O. William Werner

PRIZES.

Paul L. Mentzer—S. M. Vauclain Prize—Mechanical Drawing.
James Ballantyne—Robert W. Lesley Prize—Architectural Drawing.
Herman Schaaf—J. B. McCall Prize—Mathematics.
Charles H. Buckler—Wilfred Lewis Prize—Mechanics.
Emil de Bruijn—New York Shipbuilding Corporation Prize—Naval Architecture.

ALUMNI PRIZES.

Herman Schaaf
Mathematics
Charles H. Buckler
Mechanics
Emil de Bruijn
Naval Architecture
Paul L. Mentzer
Mechanical Drawing
James Ballantyne
Architectural Drawing

FREE MEMBERSHIP FOR ONE YEAR IN THE ASSOCIATION AWARDED TO GRADUATES.

Walter Bird
Samuel H. Collins
Anthony R. Finnigan
Francis A. Harden
Paul L. Mentzer
John Mitchell
George Nairn
Oliver Patton
Wilson D. Scott
Frederick G. Spellier

HONORABLE MENTION CERTIFICATES.

DEPARTMENT OF MATHEMATICS.

Walter Bird
Charles W. Earley
Joseph Kroulik
David McCartney
C. E. McClintock
Russell Morehouse
Harry Riley
Herman Schaaf
Wilson D. Scott
Benjamin A. Wilson

DEPARTMENT OF DRAWING.

Samuel Brethwaite
Israel Cramer
Catherine Day
Ida Sylvia Frost
William H. Gardner
Sarah J. Harvey
Joseph V. Hutelmyer
Herbert Jacobs
John V. Lindsay
Paul L. Mentzer
Herbert J. Morrill
Harry C. Meyer
George Nairn
George F. Palmer
Oliver Patton
Olive M. Stier

DEPARTMENT OF NAVAL ARCHITECTURE.

Harold B. Buckley
George F. Buckman
Emil de Bruijn
Ernest D. Hosking
Raymond H. MacAran
William J. Stanton
Joseph I. Tabakin
Charles M. Yater

MEMBERSHIP NOTES.

ELECTIONS TO MEMBERSHIP.

(Stated Meeting, Board of Managers, May 14, 1919.)

NON-RESIDENT.

MR. EARL H. WELTZ, Chemist, E. I. du Pont de Nemours & Company, and for mail, Riverside Club, Pennsgrove, New Jersey.

CHANGES OF ADDRESS.

MAJOR JOHN H. BARR, care of Remington Typewriter Company, 374 Broadway, New York City, New York.

CAPTAIN LUCIUS P. BROWN, Love Field, care of Camp Surgeon, Dallas, Texas.

MR. JOHN CALDER, The Engineers' Club, 32 West 40th Street, New York City, New York.

MR. E. M. FITZ, Room 611, New First National Bank Building, Columbus, Ohio.

MR. H. GOODWIN, JR., Power and Mining Department, General Electric Company, Schenectady, New York.

MR. RICHARD P. HARVEY, 71 First Street, San Francisco, California.

MR. EDWARD HEITMANN, Fairmount Hotel, 2595 Boulevard, Jersey City, New Jersey.

MR. WILLIAM HOPPIN, 1521 Mt. Vernon Street, Philadelphia, Pennsylvania.

MR. CLINTON N. LAIRD, Room 918, 156 Fifth Avenue, New York City, New York.

MR. ARTHUR W. LOWE, 1224 Herbert Street, Frankford, Philadelphia, Pennsylvania.

MR. THOMAS S. MARTIN, Hermit Lane, Roxborough, Philadelphia, Pennsylvania.

MR. H. H. MAXFIELD, Pennsylvania Railroad Company, Altoona, Pennsylvania.

MR. WILLIAM S. MURRAY, 165 Broadway, New York City, New York.

MR. H. B. OATLEY, 145 Wilson Avenue, Flushing, New York.

MR. L. T. SHERWOOD, P. O. Box 196, Carney's Point, New Jersey.

MR. R. JOHN TITZEL, 601 Swede Street, Norristown, Pennsylvania.

MR. JOHN A. VOGLESON, 8009 Crefeldt Street, Philadelphia, Pennsylvania.

LIEUTENANT COLONEL FRED. H. WAGNER, The Lombardy Apartments, 39th Street and Stony Run Lane, Baltimore, Maryland.

MR. J. F. WARWICK, 61 Crew Street, Atlanta, Georgia.

MR. G. A. WELLS, 1067 Madison Avenue, New York City, New York.

MAJOR R. A. WIDDICOMBE, 1025 Hollywood Avenue, Chicago, Illinois.

MR. GEORGE M. YORKE, 70 Irving Place, New York City, New York.

NECROLOGY.

Thomas Skelton Harrison was born in Philadelphia on September 19, 1837, and died on May 3, 1919. Mr. Harrison was educated in the private school of John W. Faires, and later entered the University of Pennsylvania. Finding commercial life more attractive than the learned professions, he discontinued his studies at the University and obtained a position at the Pennsylvania Sugar Refinery. In July, 1861, he became Pay Master in the United States Navy and served until August, 1864.

When Mr. Harrison left the Navy he became a partner in the firm of Harrison Brothers and Company, with which he was connected for nearly forty years. For many years he served as President of the Manufacturing Chemists' Association of the United States. He also took an active interest in the Centennial celebration in Philadelphia in 1876, serving on numerous committees which were organized at that time to further the objects of the exhibition.

Mr. Harrison was prominent in public affairs in his native city. In 1871 he was appointed Consul-General of the United States at Cairo, Egypt. Mr. Harrison derived most pleasure, however, from his activities in the fields of commerce, to which he had devoted the greater part of his life. He was connected with numerous technical, military and social organizations, and became a member of The Franklin Institute on March 5, 1901.

James Hamilton Windrim was born in Philadelphia, July 4, 1840, and died at Merion, Pa., on April 26, 1919. His educational training was obtained at Girard College, to which he was admitted at an early age. On leaving the college in 1856 he began the study of architecture under John Notman, a noted architect. When twenty years of age he was engaged to take full charge of the construction and erection of one of the largest hospital buildings in Philadelphia. Upon the completion of this work he was appointed to the Pennsylvania Railroad Company's corps of architects and was placed in charge of the planning and construction of the company's Union Depot at Pittsburgh. In later years he superintended the construction of several of the larger mansions in the suburbs of Philadelphia.

Having achieved a reputation, he found his services in constant demand for important and costly public buildings, as well as private residences. Nearly all of the large cities of the East have among their chief ornaments some example of his ability as an architect. The Masonic Temple in Philadelphia is considered by many his masterpiece.

In 1871 he was appointed architect for the Girard Estate by the Board of City Trusts of Philadelphia, and in this capacity designed and superintended improvements of the real estate controlled by the Board throughout the city, and erected a number of buildings in the grounds of Girard College. In 1889 he was appointed Supervising Architect of the United States, and held this position until April, 1891, when he resigned to accept the office of Director of the Department of Public Works of the City of Philadelphia. After four years he retired from public life and resumed the practice of his profession.

Mr. Windrim became a member of the Institute on January 22, 1867.

Mr. W. H. Albertson, 334 North Preston Street, Philadelphia, Pennsylvania.

Dr. Annabella E. Richards, 2503 Maryland Avenue, Baltimore, Maryland.

LIBRARY NOTES.

PURCHASES.

American Electrochemical Society.—Transactions. Vol. 33. 1918.

Book Review Digest.—Vol. 14. 1918.

DAVIS, A. P., and WILSON, H. M.—Irrigation Engineering. 1919.

Engineering Index Annual.—Vol. 35. 1918.

GOWLAND, WILLIAM.—The Metallurgy of the Non-Ferrous Metals. 1918.

Great Britain Advisory Committee for Aeronautics.—Technical Report for 1913–1914.

HARRIS, F. S.—The Sugar Beet in America. 1919.

JOHNSON, J. E., JR.—Principles, Operation and Products of the Blast Furnace. 1918.

LIPKA, JOSEPH.—Graphical and Mechanical Computation. 1918.

SÉJOURNÉ, PAUL.—Grandes Voûtes. 6 vols. 1913–1916.

SOTHERN, J. W. M.—The Marine Steam Turbine. 1918.

SOUTHALL, J. P. C.—Mirrors, Prisms and Lenses. 1918.

STANLEY, F. A.—Punches and Dies, Layout, Construction and Use. 1919.

TRAUTWINE, J. C.—The Civil Engineer's Pocket Book. 1919.

GIFTS.

Air Reduction Sales Company, Booklets: Acetylene Generators; Airco-Vulcan Apparatus; How to Start Airco-Vulcan Torches and Equipment; An Airco Achievement—Reclaiming Railroad Frogs by the Oxy-Acetylene Process. New York City, New York, 1918–1919. (From the Company.)

American Roller Bearing Company, Bulletin No. 1004. Pittsburgh, Pennsylvania, 1919. (From the Company.)

American Saw Mill Machinery Company, Catalogues: How Americans Helped Win the War; Making Money of the Wood Lot; Catalogue No. 18. New New York City, New York, 1917. (From the Company.)

Blaw-Knox Company, Catalogue on Blawforms. Pittsburgh, Pennsylvania, 1919. (From the Company.)

Bryn Mawr College, Calendar of Graduate Courses, 1919. Bryn Mawr, Pennsylvania, 1919. (From the College.)

Carnegie Steel Company, Booklet, entitled, Tool Steels. Pittsburgh, Pennsylvania, 1918. (From the Company.)

Case School of Applied Science, Catalogue, 1918–1919. Cleveland, Ohio, 1918. (From the School.)

Central Scientific Company, Catalogues C. and F. Chicago, Illinois, no date. (From the Company.)

C. H. & E. Manufacturing Company, Inc., Bulletins Nos. 2 and 3. Milwaukee, Wisconsin, no date. (From the Company.)

Chicago, Rock Island and Pacific Railway Company, Thirty-ninth Annual Report. Chicago, Illinois, 1918. (From the Company.)

Cleveland Planer Company, Catalogue, entitled Cleveland Open Side Planers. Cleveland, Ohio, no date. (From the Company.)

Coburn Trolley Track Manufacturing Company, Catalogue No. 50. Holyoke, Massachusetts, no date. (From the Company.)

College of the City of New York, Sixty-ninth Annual Register, 1918–1919. New York, 1919. (From the College.)

Commonwealth of Massachusetts, Booklets: List of Manufacturers Authorized to Construct Massachusetts Standard Boilers; Steam-Boiler Rules; Air-Tank Regulations. Boston, Massachusetts, 1918–1919. (From the Secretary of the Commonwealth.)

Drummond Brothers, Ltd., Catalogue on Lathes. Rydes Hill, Guilford, England, no date. (From the Company.)

Dubilier, William, The Wonderful Achievements of Radiotelegraphy in War and Peace. New York City, New York, 1919. (From the Author.)

Duriron Castings Company, Bulletins Nos. 100 and 103. Dayton, Ohio, 1919. (From the Company.)

Electric Controller and Manufacturing Company, Bulletin No. 1042-B. Cleveland, Ohio, 1918. (From the Company.)

Erie Foundry Company, Catalogue F, Erie Steam Hammers. Erie, Pennsylvania, 1919. (From the Company.)

Fitchburg Machine Company, Catalogues of the Lo-Swing Lathe. Fitchburg, Massachusetts, no date. (From the Company.)

General Railway Signal Company, Bulletin No. 135. Rochester, New York, 1919. (From the Company.)

Gisholt Machine Company, Catalogue TLC–1. Madison, Wisconsin, 1919. (From the Company.)

Grand Rapids Grinding Machine Company, Drill Grinder Book. Grand Rapids, Michigan, no date. (From the Company.)

Green Fuel Economizer Company, Bulletin No. 151. Beacon, New York, 1919. (From the Company.)

Greenfield Tap and Die Corporation, Catalogue No. 41. Greenfield, Massachusetts, 1919. (From the Corporation.)

Hendrick Manufacturing Company, Book, entitled Perforated Metals. Carbondale, Pennsylvania, 1918. (From the Company.)

Hercules Electric Steel Corporation, Catalogue of High-Speed Steel. Providence, Rhode Island, 1919. (From the Corporation.)

Hyatt Roller Bearing Company, Bulletins Nos. 420 and 1550. New York City, New York, 1919. (From the Company.)

Lakewood Engineering Company, Bulletins Nos. 25 and 26. Cleveland, Ohio, 1919. (From the Company.)

Landis Machine Company, Inc., Catalogues 24 and 25. Waynesboro, Pennsylvania, 1918–1919. (From the Company.)

Lidgerwood Manufacturing Company, Book on Lidgerwood Marine Machinery. New York City, New York, 1919. (From the Company.)

Liverpool Corporation Tramways, Annual Report of the General Manager, 1918. Liverpool, England, 1919. (From the Corporation.)

McCabe Manufacturing Company, Catalogue, entitled "A Solution of Your Flanging Problems." Lawrence, Massachusetts, no date. (From the Company.)

Morse Chain Company, Publications: Silent Chain Front End Drives; Small Power Drives; Chain Drives. Ithaca, New York, 1919. (From the Company.)

Murphy Iron Works, Catalogue, entitled The Murphy Furnace. Detroit, Michigan, no date. (From the Works.)

National Acme Company, Catalogue of Auxiliary Screw-Making Machines. Cleveland, Ohio, no date. (From the Company.)

New Bedford Water Board, Forty-ninth Annual Report. New Bedford, Massachusetts, 1919. (From the Board.)

Newton Machine Works, Inc., Catalogue No. 49A. Philadelphia, Pennsylvania, no date. (From the Works.)

New York, Ontario and Western Railway Company, Annual Report. New York City, N. Y., 1918. (From the Company.)

Nicholson File Company, Catalogue, entitled "File Filosophy." Providence, Rhode Island, 1918. (From the Company.)

Oliver Instrument Company, Catalogue on the Oliver Sawing, Filing and Lapping Machines. Adrian, Michigan, no date. (From the Company.)

Ontario Bureau of Municipal Affairs, Municipal Bulletin, 1918. Toronto, Canada, 1919. (From the Bureau.)

Orr and Sembower, Inc., Bulletins of Friction Drum Hoisting Engines. Philadelphia, Pennsylvania, no date. (From the Company.)

Pennsylvania State College, General Catalogue, 1918–1919. State College, 1919. (From the College.)

Philadelphia Rapid Transit Company, Annual Report to the Stockholders. Philadelphia, Pennsylvania, 1918. (From the Company.)

Pratt and Whitney Company, Book, entitled Precision Machine Tools. New York City, New York, 1917. (From the Company.)

Precision Castings Company, Inc., Hand-Book on Die Castings. Syracuse, New York, 1919. (From the Company.)

Public Service Railway Company, Plan for a Zone System of Fares Upon the Lines of the Company, submitted to the Board of Public Utility Commissioners, 1918. Newark, New Jersey, 1919. (From the Company.)

Quigley Furnace Specialties Company, Inc., Bulletin No. 11. New York City, New York, 1919. (From the Company.)

Ransome Concrete Machinery Company, Bulletins Nos. 102 and 200. Dunellen, New Jersey, 1919. (From the Company.)

Rutgers College and the State University of New Jersey, Catalogue for 1917–1918. New Brunswick, New Jersey, 1917. (From the College.)

Sanford Riley Stoker Company, Ltd., Catalogue, entitled Riley Underfeed Stokers. Worcester, Massachusetts, 1918. (From the Company.)

Schaeffer and Budenberg Manufacturing Company, Catalogue No. 300. Brooklyn, New York, 1918. (From the Company.)

Snyder, J. E. & Son, Catalogue of Upright Drills. Worcester, Massachusetts, 1919. (From the Company.)

Strauss Bascule Bridge Company, Seventy-page Catalogue. Chicago, Illinois, 1919. (From the Company.)

Taylor Welder Company, Booklet, entitled Electric Welding. Warren, Ohio, no date. (From the Company.)

Truscon Steel Company, Catalogue on Hy-Rib and Metal Lath. Youngstown, Ohio, 1919. (From the Company.)

University of Tennessee, Manual for Engineers. Knoxville, Tennessee, 1904. (From the University.)

United Engineering and Foundry Company, Bulletin, entitled United Precision Cold Strip Mills. Pittsburgh, Pennsylvania, 1919. (From the Company.)

United States Shipping Board, Report of the Director of Marine and Dock Industrial Relations Division. Washington, District of Columbia, 1919. (From the Board.)

Waterbury Company, General Catalogue, New York City, New York, 1918. (From the Company.)

Wellman Seaver Morgan Company, Bulletin No. 19. Akron, Ohio, 1919. (From the Company.)

Winfield Electric Welding Machine Company, Catalogues: Electric Welding of High Speed Tool Steel; Directions for Installing and Operating Winfield L & M Type Spot Welding Machines. Warren, Ohio, no date. (From the Company.)

Whiting Foundry Equipment Company, Catalogue No. 135. Harvey, Illinois, no date. (From the Company.)

Whitman and Barnes Manufacturing Company, Catalogue No. 91. Akron, Ohio, 1919. (From the Company.)

Wolf Company, Catalogue No. 18. Chambersburg, Pennsylvania, no date. (From the Company.)

BOOK NOTICES.

AN INTRODUCTION TO THE PHYSICS AND CHEMISTRY OF COLLOIDS. By Emil Hatschek. Third edition, 110 pages, contents and index, illustrations, 12mo, Philadelphia, P. Blakiston's Son & Company, 1919. Price, $1.50 net.

The second edition of this work was reviewed in this JOURNAL three years ago. The present issue differs by the addition of some pages due to the incorporation of new matter. Some minor errors have been corrected. Inasmuch as since the appearance of the second edition several large text-books have been issued in English and Ostwald's "Grundriss der Kolloidchemie" is now available in English form, the author has not thought it necessary to enlarge materially the scope of the book. It is a very readable and informing summary of the important facts in the field to which it is devoted.

HENRY LEFFMANN.

PUBLICATIONS RECEIVED.

U. S. Bureau of Mines: Bulletin 169. Illinois Mining Statutes Annotated, by J. W. Thompson. Including all Illinois Mining Laws. 594 pages, 8vo. Monthly Statement of Coal-Mine Fatalities in the United States. January, 1919. List of Permissible Explosives, Lamps, and Motors Tested Prior to February 28, 1919, compiled by Albert H. Fay. 25 pages, 8vo. Technical paper 178. Notes on Lignite, Its Characteristics and Utilization, by S. M. Darling. 19 pages, 8vo. Technical paper 209. Traps for Saving Gas at Oil Wells, by W. R. Hamilton. 34 pages, illustrations, plates, 8vo. Technical paper 213. Quarry Accidents in the United States During the Calendar Year 1917, compiled by Albert H. Fay. 62 pages, 8vo. Washington, Government Printing Office, 1919.

North Carolina Geological and Economic Survey: Biennial Report of the State Geologist, 1917–1918. 110 pages, illustrations, 8vo. Raleigh, State printers, 1919.

Public Ownership: The Solution of Chicago's Transportation Problem. Suggested Constructive Program, adopted by the Chicago Municipal Ownership League (affiliated with the Public Ownership League of America) and submitted to the City Council of Chicago. 16 pages, 8vo. Chicago, Municipal Ownership League, 1919.

Railways and Waterways An Address by Walker D. Hines, Director General of Railroads. Delivered before the fourteenth convention of the National Rivers and Harbors Congress, Washington, D. C., February 7, 1919. 8 pages, 8vo.

A Gratifying Change of Front: An Address by Hon. J. Hamilton Lewis, U. S. Senator from Illinois. Delivered before the fourteenth convention of the Rivers and Harbors Congress, Washington, D. C., February 7, 1919. 7 pages, 8vo.

Commercial Production of Helium for the Inflation of Dirigibles. ANON. (*Revue Generale des Sciences,* vol. xxx, No. 7, p. 195, April 15, 1919.)—One of the most remarkable technical achievements of war-time activities is the preparation of helium in quantities sufficient for the inflation of dirigibles. Helium is a light gas, comparable in this respect with hydrogen, and possessing a lifting force of 92 per cent. of the latter. It has the very great advantage over hydrogen in being neither inflammable nor explosive, properties which make it possible to place the operating motors within the gas bag; moreover, the diffusion losses of helium are less than those of hydrogen.

Helium is abundant in the sun but is rare on the surface of the earth, where it is only found with the gases given off by heating certain radio-active minerals or in certain natural gases. Before the war, only very small amounts had been collected, and at a very high cost. On the recommendation of Sir R. Threlfall, who had made an extensive study of the sources of helium and the costs of its preparation and transportation, the British admiralty undertook the further development of the project. It was found that certain natural gases of Canada contain about ⅓ per cent. of helium, and a research laboratory for the purpose was established at the University of Toronto. When the United States entered the war, the United States Bureau of Mines also took up the project with the object of exploiting the sources of helium of the country. Due to the vigorous prosecution of this work, the industrial production of helium was established in 1918. When hostilities ceased, 4100 cubic metres of almost pure helium were at hand, compressed and ready for transport, and plants were already under construction for the manufacture of 1400 cubic metres of helium per day at a price not exceeding 18 francs per cubic metre.

CURRENT TOPICS.

Improving the Quality of Gray Iron by the Electric Furnace. G. K. ELLIOTT. (*Proceedings of the American Electrochemical Society*, April 3–5, 1919.)—All ordinary grades of gray iron—those with medium and high percentages of phosphorus—cannot be melted more easily or more economically than in the cupola. For melting efficiency, this furnace takes precedence over its two closest rivals, the reverberatory or air-furnace, and the regenerative open-hearth furnace. For simplicity of construction, low cost of installation and up-keep, ease of operation, and economy of melting, it has no competitors; and there is no probability that, for the great run of ordinary gray-iron castings, it will ever be displaced, although its improvement is conceivable. From the standpoint of process alone, the cupola is almost impeccable; but from the high ground of product, it shows serious faults. The cupola is not a refining furnace, and sometimes its hottest iron is not hot enough for the best casting results. Supertenacious and solid iron demands the attainment of hotter iron. This requires either the elimination of the cupola or the introduction of a duplex process.

For a superheating furnace, supplemental to the cupola, there are several eligible types. Among these are the reverberatory furnace, the regenerative furnace, and the electric furnace. For really extraordinary castings the author believes the arc electric furnace presents the most promising possibilities. The foundry with which the author has been connected has made a specialty of high-pressure steam valve castings with extreme solidity exacted. Experience in the manufacture of this product has indicated that the basic-bottom arc electric furnace is the best auxiliary for the cupola in a duplex process for the production of truly high-grade gray-iron castings. Carbon regulation, total as well as combined and graphitic, is possible to a most useful extent in the electric furnace, and the basic electric furnace removes most of the sulphur while the metal is being superheated. Another advantage accruing from the electric furnace is the possibility of making furnace additions of manganese and other elements for particular purposes without having to expect more or less appreciable losses; the manganese losses are *nil*. The electric furnace duplex process for gray iron is not recommended as a commercial practicability for ordinary iron castings under ordinary circumstances, but rather as a convenient and extremely efficacious substitute for the cupola process for extraordinary castings or for extraordinary circumstances.

New Outline Map of the United States on the Lambert Projection. ANON. (*Circular, U. S. Coast and Geodetic Survey*, May 20, 1919.)—Many methods of projection have been designed to solve the difficult problem of representing a spherical surface on a plane. As different projections have unquestionable merits as well as equally serious defects, any region to be mapped should be made the subject of special study and that system of projection adopted which will give the best results for the area under consideration. The Mercator Projection, almost universally used for nautical charts, is responsible for many false impressions of the relative size of countries differing in latitude. The polyconic projection, widely used and well adapted for both topographic and hydrographic surveys, when used for the whole of the United States in one map, has the serious defect of unduly exaggerating the areas on its eastern and western limits.

The U. S. Coast and Geodetic Survey, Department of Commerce, reports the completion of the new outline map of the United States on the Lambert Conformal Conic Projection, scale 1-5,000,000, dimensions, 25 x 39 inches, price, 25 cents. This map is intended merely as a base to which may be added any kind of special information desired. The shoreline is compiled from the most recent Coast and Geodetic Survey charts. State names and boundaries, principal rivers, capitals and largest cities in the different states, are the only information otherwise embodied.

The map is of special interest from the fact that it is based on the same system of projection as that which was employed by the armies of the allied forces in the military operations in France. To meet those requirements and at the request of the army, special publications were prepared by the Coast and Geodetic Survey. The value of the new outline map on the Lambert projection can best be realized when it is stated that throughout the larger and most important part of the United States, that is, between latitudes 30½° and 49° the maximum scale error is only one-half of one per cent. This amount of scale error of one-half of one per cent. is frequently less than the distortion due to the method of printing and to changes from the humidity of the air. Only in southernmost Florida and Texas does this projection attain its maximum error of 2⅓ per cent.

PRESS OF
J. B. LIPPINCOTT COMPANY
PHILADELPHIA

INDEX TO VOL. 187.

Absorption of water by gelatine (Shreve), 319
Airplanes, Visibility of (Luckiesh), 289, 409
Aluminum, Metallography of (Anderson), 1
ANDERSON, ROBERT J.: Metallography of aluminum, 1

BANCROFT, WILDER D.: The color of water, 249, 459
BOOK NOTICES:
Aldred lectures on engineering practice, 1917–1918, 375
Bibliography of American literature relating to refrigeration, compiled by Peter Neff, 125
France, Bureau des Longitudes, annuaire, 1919, 523
Hatschek, E.: An introduction to the physics and chemistry of colloids, 765
Hawk, Philip B.: Practical physiological chemistry, 126
Maxted, Edward B.: Catalytic hydrogenation and reduction, 652
Meade, Richard K.: The chemist's pocket manual, 126
Ostwald, Wolfgang: A handbook of colloidal chemistry, 375
Smith, Edgar F.: Chemistry in old Philadelphia, 652
Stoddard, John Tappan: Introduction to organic chemistry, 126
Strong, W. W.: The new science of the fundamental physics, 374
U. S. Tariff Commission: Dyes and other coal-tar chemicals, 374
Villavecchia, Vittorio: Treatise on applied analytical chemistry, vol. ii, 522
Wiley, Harvey W.: Beverages and their adulteration, 520
Willows, R. S., and E. Hatschek, Surface tension and surface energy, 523

Color of water (Bancroft), 249, 459
Conductivity, electrolytic, in non-aqueous solutions (Creighton), 313
COPE, THOMAS D.: An application of the radiometer to the measurement of the electric current, 737
CREIGHTON, HENRY JERMAIN MAUDE: Electrolytic conductivity in non-aqueous solutions. III. Relations between the conductivity of the solute and several physical properties of the solvent, 313
CREIGHTON, HENRY JERMAIN MAUDE: How the nitrogen problem has been solved, 377, 599, 705
CULVER, CHARLES A.: Transatlantic radio reception, 529
CURRENT TOPICS, 48, 63, 64, 97, 109, 114, 116, 128, 170, 214, 224, 226, 228, 246, 271, 272, 337, 355, 358, 362, 365, 458, 485, 494, 496, 498, 502, 512, 524, 525, 579, 580, 598, 626, 632, 634, 654, 655, 688, 703, 704, 735, 736, 744, 748, 749, 750, 752, 766, 767
Eastman Kodak Company, Research Laboratory Notes, 227, 357, 497, 633, 747
Electric current measurement. An application of the radiometer to (Cope), 737
FRANKLIN INSTITUTE:
Library notes, 125, 244, 374, 520, 650, 761
Members doing civilian work for the government, 120, 236.
Members in the active military or naval service, 118, 234
Membership notes, 124, 242, 369, 514, 643, 760
President's report, 238
School, Annual Report of the Director, 756
Science and the Arts Committee, stated meetings: December 4, 1918, 122; January 8, 1919, 242; February 5, 1919, 369; March 5, 1919, 514; April 2, 1919, 642; May 7, 1919, 756
Sections, 123, 242, 369, 642
Standing committees, 1919, 368
Stated Meetings, Proceedings: December 18, 1918, 117; January 15, 1919, 233; February 19, 1919, 367; March 19, 1919, 513; April 16, 1919, 639; May 21, 1919, 755
Gelatine, Absorption of water by (Shreve), 319
General Electric Company, Research Laboratory Notes, 359, 635, 749
GERHARD, WM. PAUL: The relative merits of cast-iron, wrought-iron, and steel pipe for house drainage purposes, 99

HITCHINS, ALFRED B.: Modern applications of photography, 129
House drainage, The relative merits of cast-iron, wrought-iron, and steel pipe for house drainage purposes (Gerhard), 99
Hudson River, Vehicular tunnels under the (Schreiber), 273

Indicating instruments, The concept of resilience with respect to (Schlink), 147
Institute of Industrial Research Notes, 115
Institutes of applied science (Nutting), 487

KING, LOUIS V.: On the determination of the electrical and acoustic characteristics of telephone receivers, 611

LANDAU, DAVID, and PERCY H. PARR: A new theory of plate springs, 65, 199
LANGLEY, SAMUEL PIERPONT: Pioneer in practical aviation (Leffmann), 49
LEFFMANN, HENRY: A tribute. Samuel Pierpont Langley: pioneer in practical aviation, 49
LUCKIESH, M.: The visibility of airplanes, 289, 409

Metallography of aluminum, (Anderson), 1
Metals, Vapor tensions of the (Richards), 581

Nela Research Laboratory Notes, 225
Nitrogen fixation (Creighton), 377, 599, 705
Nitrogen problem, How it has been solved (Creighton), 377, 599, 705
NUTTING, P. G.: Institutes of applied science, 487

Oil shales (Winchester), 689

PARR, PERCY H., and DAVID LANDAU: A new theory of plate springs, 65, 199
Photography, Modern applications of (Hitchins), 129
Pipe, Cast-iron, wrought-iron, and steel, Relative merits of, for house drainage purposes (Gerhard), 99
Plate springs, A new theory of (Landau and Parr), 65, 199
Publications received, 127, 244, 376, 524, 653, 765

Radio reception, Transatlantic (Culver), 529
Radiometer, An application of the, to the measurement of the electric current (Cope), 737
Resilience, The concept of (Schlink), 147
RICHARDS, JOSEPH W.: The vapor tensions of the metals, 581

SCHLINK, FREDERICK J.: The concept of resilience with respect to indicating instruments, 147
SCHREIBER, MARTIN: Vehicular tunnels under the Hudson River, 273
Science, applied, Institutes of (Nutting), 487
Shales, Oil (Winchester), 689
SHELTON, F. H.: Windmills, picturesque and historic: the motors of the past, 171
SHREVE, EDITH B.: Investigations on the absorption of water by gelatine, 319
Solutions, non-aqueous, Electrolytic conductivity in (Creighton), 313
Springs, plate, A new theory of (Landau and Parr), 65, 199
SQUIER, GEORGE OWEN: Tree telephony and telegraphy, 657

Telegraphy, Tree (Squier), 657
Telephone receivers, Electrical and acoustic properties of (King), 611
Telephony, Tree (Squier), 657
Transatlantic radio reception (Culver), 529
Tree telephony and telegraphy (Squier), 657
Tunnels, Vehicular, under the Hudson River (Schreiber), 273

United Gas Improvement Company, Physical Laboratory Notes, 499
U. S. Bureau of Chemistry Notes, 229, 363, 503, 637, 751
U. S. Bureau of Mines Notes, 753
U. S. Bureau of Standards Notes, 111, 215, 339, 495, 627, 745

Vapor tensions of the metals (Richards), 581
Visibility of airplanes (Luckiesh), 289, 409

Water, Color of (Bancroft), 249, 459
Westinghouse Electric and Manufacturing Company, Research Laboratory Notes, 507
WINCHESTER, DEAN E.: Oil shales, 689
Windmills (Shelton), 171

OFFICERS FOR 1919

PRESIDENT	WALTON CLARK
VICE-PRESIDENTS	HENRY HOWSON
	COLEMAN SELLERS, JR.
SECRETARY	R. B. OWENS
TREASURER	CYRUS BORGNER

BOARD OF MANAGERS

GELLERT ALLEMAN	GEORGE R. HENDERSON
FRANCIS T. CHAMBERS	CHARLES A. HEXAMER
G. H. CLAMER	GEORGE A. HOADLEY
THEOBALD F. CLARK	HARRY F. KELLER
CHARLES DAY	ROBERT W. LESLEY
KERN DODGE	MARSHALL S. MORGAN
W. C. L. EGLIN	EDW. V. MCCAFFREY
WALTON FORSTALL	LAWRENCE T. PAUL
BENJAMIN FRANKLIN	JAMES S. ROGERS
ALFRED W. GIBBS	GEO. D. ROSENGARTEN
ALFRED C. HARRISON	E. H. SANBORN
NATHAN HAYWARD	WILLIAM C. WETHERILL

BOARD OF TRUSTEES

JOSEPH C. FRALEY, President

WILLIAM L. AUSTIN	JOHN GRIBBEL
CHARLES E. BRINLEY	ALFRED C. HARRISON
WALTON CLARK	FREDERICK ROSENGARTEN

The Board of Trustees was formed in accordance with the following By-Laws passed in the year 1887:

> All Real and Personal Estate of the Institute which may hereafter be acquired by voluntary subscription or devise, bequest, donation, or in any way other than through its own earnings or by investment of its own funds, saving where the donors shall expressly provide to the contrary, shall be taken as acquired upon the condition that the same shall be vested in a Board of Trustees, who shall be appointed in the manner hereinafter indicated. Unless the title to such property shall be directly vested in said Board of Trustees by the donors, the Institute, by deed attested by the President and Secretary, which they are hereby authorized to execute and deliver, shall forthwith convey the same to said Trustees, who shall hold it in trust for the purposes specifically designated by the donors; or, if there shall be no specific designation, for the benefit of the Institute in the way and manner hereinafter provided, so that the same shall not, in any event be liable for the debts of the Institute.

This method of separating the *body holding* the principal of the various funds from the Board of Managers, the *spending body*, is an original idea of The Franklin Institute and it is hoped it will appeal to friends who may desire to create funds to further the objects of the Institute, and the various branches of science in which they may be interested.

MEMBERSHIP.

Terms and Privileges.

THE MEMBERSHIP OF THE INSTITUTE is divided into the following classes, viz.: *Resident Members, Stockholders, Life Members, Permanent Members, Non-resident and Associate Members.*

Any one interested in the purposes and objects of The Institute and expressing a willingness to further the same may become a member when proposed by a member in good standing and elected by the Board of Managers.

TERMS.—Resident members pay Fifteen Dollars each year. The payment of Two Hundred Dollars in any one year secures Life Membership, with exemption from annual dues.

STOCK.—Second-class stockholders pay an annual tax of Twelve Dollars per share, and the holder of one share is entitled by such payment to the privileges of membership.

PRIVILEGES.—Each contributing member (including non-residents) and adult holder of second-class stock is entitled to participate in the meetings of The Institute, to use the Library and Reading Room, to vote at the Annual Election for officers, to receive tickets to the lectures for himself and friend, to attend the Section meetings and to receive one copy of the JOURNAL *free* of charge, except associate members, who may not take part in elections.

PERMANENT MEMBERS.—The Board of Managers may grant to any one who shall in any one year contribute to The Institute the sum of One Thousand Dollars a permanent membership, transferable by will or otherwise.

NON-RESIDENT MEMBERS.—Newly elected members residing permanently at a distance of twenty-five miles or more from Philadelphia may be enrolled as Non-resident Members, and are required to pay an entrance fee of Five Dollars, and Five Dollars annually. Non-resident Life Membership, $75.00.

Contributing members, if eligible, under the non-resident clause, on making request therefor, may be transferred to the non-resident class by vote of the Board of Managers, and are required to pay Five Dollars annually.

ASSOCIATE MEMBERS.—Associate members are accorded all the privileges of The Institute, except the right to vote or hold office, upon the payment of annual dues of Five Dollars. This class of membership is limited to persons between the ages of seventeen and twenty-five years. Upon reaching the age limit they become eligible to the other classes of membership.

RESIGNATIONS *must be made in writing, and dues must be paid to the date of resignation.*

For further information and membership application blanks address the SECRETARY of THE INSTITUTE.

AWARDS BY THE INSTITUTE

The following awards are made by, or on the recommendation of, The Franklin Institute:

The Franklin Medal (Gold Medal and Diploma).—This medal is awarded annually from the Franklin Medal Fund, founded January 1, 1914, by Samuel Insull, Esq., to those workers in physical science or technology, without regard to country, whose efforts, in the opinion of the Institute, acting through its Committee on Science and the Arts, have done most to advance a knowledge of physical science or its applications.

The Elliott Cresson Medal (Gold Medal and Diploma).—This medal is awarded for discovery or original research, adding to the sum of human knowledge, irrespective of commercial value; leading and practical utilizations of discovery; and invention, methods or products embodying substantial elements of leadership in their respective classes, or unusual skill or perfection in workmanship.

The Howard N. Potts Medal (Gold Medal and Diploma).—This medal is awarded for distinguished work in science or the arts; important development of previous basic discoveries; inventions or products of superior excellence or utilizing important principles; and for papers of especial merit that have been presented to the Institute and published in its JOURNAL.

The Edward Longstreth Medal of Merit (Silver Medal and Diploma).—This medal, with a money premium when the accumulated interest of the fund permits, is awarded for meritorious work in science or the arts; including papers relating to such subjects originally read before the Institute, and papers presented to the Institute and published in its JOURNAL. In the event of an accumulation of the fund for medals beyond the sum of one hundred dollars, it is competent for the Committee on Science and the Arts to offer from such surplus a money premium for some special work on any mechanical or scientific subject that is considered of sufficient importance, or for meritorious papers presented to the Institute and published in its JOURNAL.

The Certificate of Merit.—A Certificate of Merit is awarded to persons adjudged worthy thereof for their inventions, discoveries or productions.

The Boyden Premium.—Uriah A. Boyden, Esq., of Boston, Mass., has deposited with THE FRANKLIN INSTITUTE the sum of one thousand dollars, to be awarded as premium to "any resident of North America who shall determine by experiment whether all rays of light, and other physical rays, are or are not transmitted with the same velocity."

For further information relating to these awards apply to the Secretary of the Institute.

THE FRANKLIN INSTITUTE AWARDS

Notice is hereby given that THE FRANKLIN INSTITUTE, through its Committee on Science and the Arts, will recommend the award of

THE HOWARD N. POTTS GOLD MEDAL

To

CLARENCE P. LANDRETH

PHILADELPHIA, PA.

For his

ELECTROLYTIC SEWAGE PROCESS

Any objection to the above recommendation, based on evidence of lack of merit, should be communicated within three months of the date of this notice to the Secretary of THE FRANKLIN INSTITUTE, Philadelphia.

R. B. OWENS,
Secretary.

HALL OF THE INSTITUTE
June, 1919.

THE FRANKLIN INSTITUTE AWARDS

Notice is hereby given that THE FRANKLIN INSTITUTE, through its Committee on Science and the Arts, will recommend the award of

THE HOWARD N. POTTS GOLD MEDAL

Jointly to

REYNOLD JANNEY
NEW YORK, N. Y.

AND

HARVEY D. WILLIAMS
WALLINGFORD, CONN.

For the Invention of the

WATERBURY HYDRAULIC SPEED GEAR

Any objection to the above recommendation, based on evidence of lack of merit, should be communicated within three months of the date of this notice to the Secretary of THE FRANKLIN INSTITUTE, Philadelphia.

R. B. OWENS,
Secretary.

HALL OF THE INSTITUTE
June, 1919.

FIDELITY TRUST COMPANY

Nos. 325-331 CHESTNUT ST. Nos. 43-53 SOUTH FOURTH ST.
BROAD ST. OFFICE: N. E. COR. BROAD AND CHESTNUT STS.

Capital, $5,000,000
Surplus, $16,000,000

Pays Interest on Deposits
Safes for Rent in Burglar-proof Vaults.
Executes Trusts of Every Description
Securities and Valuables Taken for Safe Keeping.
Wills Safely Kept Without Charge

HAMLIN & MORRISON
ANALYTICAL CHEMISTS
FORREST BUILDING
PHILADELPHIA

Riehlé Bros. Testing Machine Co.
Engineers, Founders, Machinists
1424 N. 9th St., Philadelphia, Pa.
Telephone Connection. Cable, "Riehle."
Correspondence Solicited from Parties desiring the Latest Improved United States Standard Testing Machinery and Appliances of all varieties and capacities.

BANCROFT & BROTHER
ESTABLISHED 1868
INSURANCE IN ALL ITS BRANCHES
264 Drexel Building, Philadelphia

High and Low Pressure
STEAM FITTING
PLUMBING
John Borden and Bro.
687 North 19th Street

ELEPHANT BRAND
DELTA
REG. U.S. PAT. OFF.
THE PHOSPHOR BRONZE SMELTING CO.
2200 WASHINGTON AVENUE, PHILADELPHIA, PA.
ELEPHANT BRAND Phosphor Bronze
INGOTS, CASTINGS, WIRE, SHEETS, RODS, Etc.
— DELTA METAL —
IN BARS FOR FORGING AND FINISHED RODS
ORIGINAL AND SOLE MAKERS IN THE U.S.

THE MOORE & WHITE CO.

PHILADELPHIA, PA., U.S.A.

Builders of { Paper-making Machinery
Friction Clutch Pulleys
Variable Speed Changes